OMB Number: 4040-0004
Expiration Date: 8/31/2016

Application for Federal Assistance SF-424

* 1. Type of Submission:
- [ ] Preapplication
- [x] Application
- [ ] Changed/Corrected Application

* 2. Type of Application:
- [x] New
- [ ] Continuation
- [ ] Revision

* If Revision, select appropriate letter(s):

* Other (Specify):

* 3. Date Received: 04/21/2016

4. Applicant Identifier: 8801

5a. Federal Entity Identifier:

5b. Federal Award Identifier:

State Use Only:

6. Date Received by State:

7. State Application Identifier:

8. APPLICANT INFORMATION:

* a. Legal Name: Northeastern University

* b. Employer/Taxpayer Identification Number (EIN/TIN): (b) (4)

* c. Organizational DUNS: 0014236310000

d. Address:

* Street1: 360 Huntington Ave
Street2: 490 RP
* City: Boston
County/Parish:
* State: MA: Massachusetts
Province:
* Country: USA: UNITED STATES
* Zip / Postal Code: 021155005

e. Organizational Unit:

Department Name: Marine Science Center

Division Name: College of Science

f. Name and contact information of person to be contacted on matters involving this application:

Prefix:
* First Name: Randall
Middle Name:
* Last Name: Hughes
Suffix:

Title: Assistant Professor

Organizational Affiliation: Northeastern University

* Telephone Number: (781) 581-7370
Fax Number: (781) 581-6076

* Email: ann.hughes@neu.edu

Application for Federal Assistance SF-424

*** 9. Type of Applicant 1: Select Applicant Type:**

O: Private Institution of Higher Education

Type of Applicant 2: Select Applicant Type:

Type of Applicant 3: Select Applicant Type:

* Other (specify):

*** 10. Name of Federal Agency:**

Environmental Protection Agency

11. Catalog of Federal Domestic Assistance Number:

66.509

CFDA Title:

Science To Achieve Results (STAR) Research Program

*** 12. Funding Opportunity Number:**

EPA-G2016-STAR-A1

* Title:

Integrating Human Health and Well-Being with Ecosystem Services

13. Competition Identification Number:

NONE

Title:

14. Areas Affected by Project (Cities, Counties, States, etc.):

Add Attachment | Delete Attachment | View Attachment

*** 15. Descriptive Title of Applicant's Project:**

Managing for social-ecological resilience: Integrating ecosystem function and societal values into a decision support toolkit for oyster fishery sustainability

Attach supporting documents as specified in agency instructions.

Add Attachments | Delete Attachments | View Attachments

Application for Federal Assistance SF-424

16. Congressional Districts Of:

* a. Applicant: MA-007 * b. Program/Project: MA-007

Attach an additional list of Program/Project Congressional Districts if needed.

Add Attachment | Delete Attachment | View Attachment

17. Proposed Project:

* a. Start Date: 04/01/2017 * b. End Date: 03/31/2020

18. Estimated Funding ($):

* a. Federal	598,939.00
* b. Applicant	0.00
* c. State	0.00
* d. Local	0.00
* e. Other	0.00
* f. Program Income	0.00
* g. TOTAL	598,939.00

*** 19. Is Application Subject to Review By State Under Executive Order 12372 Process?**

☐ a. This application was made available to the State under the Executive Order 12372 Process for review on .

☐ b. Program is subject to E.O. 12372 but has not been selected by the State for review.

☒ c. Program is not covered by E.O. 12372.

*** 20. Is the Applicant Delinquent On Any Federal Debt? (If "Yes," provide explanation in attachment.)**

☐ Yes ☒ No

If "Yes", provide explanation and attach

Add Attachment | Delete Attachment | View Attachment

21. *By signing this application, I certify (1) to the statements contained in the list of certifications and (2) that the statements herein are true, complete and accurate to the best of my knowledge. I also provide the required assurances** and agree to comply with any resulting terms if I accept an award. I am aware that any false, fictitious, or fraudulent statements or claims may subject me to criminal, civil, or administrative penalties. (U.S. Code, Title 218, Section 1001)**

☒ ** I AGREE

** The list of certifications and assurances, or an internet site where you may obtain this list, is contained in the announcement or agency specific instructions.

Authorized Representative:

Prefix: * First Name: Eric

Middle Name:

* Last Name: Jones

Suffix:

* Title: Senior Grant Officer

* Telephone Number: (617) 373-5600 Fax Number:

* Email: oraf@neu.edu

* Signature of Authorized Representative: Eric Jones * Date Signed: 04/21/2016

OMB Number: 2030-0020
Expiration Date: 06/30/2017

EPA KEY CONTACTS FORM

Authorized Representative: *Original awards and amendments will be sent to this individual for review and acceptance, unless otherwise indicated.*

Name: **Prefix:** | **First Name:** Dana | **Middle Name:**
Last Name: Carroll | **Suffix:**
Title: Associate Vice Provost

Complete Address:

Street1: 360 Huntington Ave
Street2: 490 RP
City: Boston | **State:** MA: Massachusetts
Zip / Postal Code: 021155005 | **Country:** USA: UNITED STATES
Phone Number: 617-373-5600 | **Fax Number:**
E-mail Address: oraf@neu.edu

Payee: *Individual authorized to accept payments.*

Name: **Prefix:** | **First Name:** Doris | **Middle Name:**
Last Name: Schultz | **Suffix:**
Title: Director of Research Finance

Complete Address:

Street1: 320 Huntington Ave
Street2: 390 RP
City: Boston | **State:** MA: Massachusetts
Zip / Postal Code: 021155005 | **Country:** USA: UNITED STATES
Phone Number: (617) 373-6504 | **Fax Number:**
E-mail Address: d.schultz@neu.edu

Administrative Contact: *Individual from Sponsored Programs Office to contact concerning administrative matters (i.e., indirect cost rate computation, rebudgeting requests etc).*

Name: **Prefix:** | **First Name:** Eric | **Middle Name:**
Last Name: Jones | **Suffix:**
Title: Senior Grants Officer

Complete Address:

Street1: 360 Huntington Ave
Street2: 490 RP
City: Boston | **State:** MA: Massachusetts
Zip / Postal Code: 021155005 | **Country:** USA: UNITED STATES
Phone Number: 617-373-5313 | **Fax Number:**
E-mail Address: ep.jones@neu.edu

EPA KEY CONTACTS FORM

Project Manager: *Individual responsible for the technical completion of the proposed work.*

Name: **Prefix:** | **First Name:** Randall | **Middle Name:**

Last Name: Hughes | **Suffix:**

Title: Assistant Professor

Complete Address:

Street1: 430 Nahant Rd

Street2:

City: Nahant | **State:** MA: Massachusetts

Zip / Postal Code: 01908 | **Country:** USA: UNITED STATES

Phone Number: 781-581-7370 | **Fax Number:** 781-581-6076

E-mail Address: rhughes@neu.edu

Managing for social-ecological resilience: Integrating ecosystem function and societal values into a decision-support toolkit for oyster fishery sustainability

TABLE OF CONTENTS

ABSTRACT
Funding Opportunity Title and Number: Integrating Human Health and Well-Being with Ecosystem Services (EPA-G2016-STAR-A1)

Project Title: Managing for social-ecological resilience: Integrating ecosystem function and societal values into a decision-support toolkit for oyster fishery sustainability

Investigators: Lead PI: A. Randall Hughes, (rhughes@neu.edu); Co-PI: Steven Scyphers

Institution: Northeastern University, Boston, MA

Project Period and Location: April 1, 2017 - March 31, 2020; Apalachicola Bay, Florida, and Northeastern University, Nahant, MA

Project Cost: $598,939

Project Summary: *Objectives and Hypotheses*: We will evaluate ecosystem services provided by oyster habitat in three socio-environmental management contexts (public natural oyster reefs, private on-bottom oyster leases, and private off-bottom aquaculture), their response to multiple stressors, the social values attached to these services, and their implications for ecosystem management and human well-being. We hypothesize that the diversification of the oyster fishery will enhance both social and ecological sustainability. In Objective 1, we will synthesize existing ecological data on the ecosystem services provided by oyster reefs and compare them to existing and new data in our focal estuary, Apalachicola Bay, Florida. In Objective 2, we will document social values, beliefs, and norms in the coastal communities of Apalachicola Bay. In Objective 3, we will integrate the data collected in objectives 1 and 2 on social values and ecosystem services of different oyster management contexts to inform decision making and management strategies. *Experimental Approach*: Combining a literature synthesis and collection of field data, we will assess the quantity and quality of the oyster production, provision of habitat for invertebrates and fishes, and risk posed by the human pathogen *Vibrio vulnificus* across oyster management contexts. We will complement these ecological data with a socioeconomic survey to assess social values associated with commercial and recreational fishing, seafood processing and consumption, as well as the implications of key stressors and socio-environmental management strategies on individual and community well-being. *Expected Results*: This project will leverage and enhance The Nature Conservancy's Coastal Resilience online mapping tool (http://maps.coastalresilience.org/gulfmex) by facilitating the development of a new Management Effectiveness web app that supports restoration and recovery decisions in planning to maximize ecological, social, and economic benefits.

Supplemental Keywords: analytical; community-based; coastal resilience; decision making**;** decision support; ecological effects; ecosystem; estuary; Florida (FL); habitat; marine science; restoration; social science; stressor; survey; vulnerability; viruses; web mapping

RESEARCH PLAN

Background/Rationale

Recreational and commercial fishermen, as well as numerous other stakeholders in coastal communities, are directly affected by the health and management of fisheries. Meanwhile, coastal ecosystems are also strongly influenced by the actions of recreational anglers and commercial fishermen, and the management and policy contexts of coastal communities. Recent studies have revealed that efforts to protect or rebuild ecosystems are only successful when the views of key stakeholders and broader society are considered and used to help guide management efforts. In other words, coastal fisheries, including social and economic dimensions, and coastal ecosystems are tightly coupled, and thus serve as a tractable example of a social-ecological system (SES; Fig. 1; Collins et al. 2011). Integrating an understanding of SES dynamics into community planning and ecosystem-based management, however, requires disentangling how the structure, function, and identity of tightly coupled human and natural systems are affected by environmental change and stressors, and how these perturbations feedback and affect ecosystem processes (Adger et al. 2005).

One workable solution for resource-dependent societies, such as coastal fishing communities, may involve increasing social-ecological diversity. Diversity has long been recognized as a key component of stability in both human and ecological systems. Stock market investments are built on the principle of diversification to manage risk: because many individual stocks fluctuate independently, having a diverse portfolio buffers against variability. This same "portfolio effect" applies in natural systems, where diversity enhances the stability of ecosystem processes and the services they provide to humans (MacArthur 1955, Elton 1958, Cardinale et al. 2012). Although typically thought of in terms of the number of species present, diversity can occur at multiple levels, including within a single species, with significant effects for ecological processes (Hughes et al. 2008). For instance, in Bristol Bay, Alaska, division of the salmon fishery into distinct fishing districts encompassing multiple breeding populations has led to an estimated ten-fold reduction in fishery closures because these breeding populations fluctuate independently rather than increasing or declining in concert (Schindler et al. 2010). Fishery diversity has also stabilized other ecosystem processes supported by the salmon, with benefits for the human communities that depend on them (Schindler et al. 2010). Positive effects of diversity on ecosystem stability are often strongest in response to stressors (Hughes and Stachowicz 2004, Isbell et al. 2015). Despite the potential for portfolio effects to enhance stability and resilience in many harvested species, they are seldom considered and

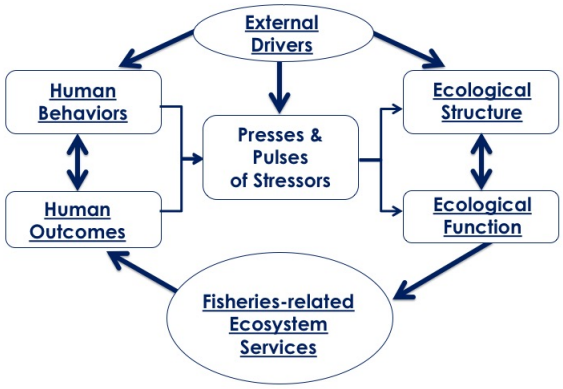


Figure 1. Conceptual social-ecological system highlighting the linkages among fisheries, ecosystems, and stressors (adapted from Collins et al. 2011).

incorporated into resource and ecosystem management efforts (Kasperski and Holland 2013).

Stability-conferring effects of diversity are particularly important in estuaries, which supply over 50% of the United States' annual fishery harvest from relatively few species (Houde and Rutherford 1993, NMFS 2014). For centuries, one of the primary coastal fisheries throughout much of the United States has been oysters, which are also considered "ecosystem engineers" (Jones et al. 1997) and provide human societies with a wide array of ecosystem services (Grabowski and Peterson 2007, Grabowski et al. 2012). For instance, oyster reefs serve as a key habitat for a range of recreationally and commercially valuable estuarine fishes and invertebrates (Wells 1961, Bahr and Lanier 1981, Lenihan and Peterson 1998, Peterson et al. 2003). In addition, **oysters filter large volumes of water, removing excess nitrogen from the water and filtering down the abundance of harmful algae, microbes, and pollutants** (Dame et al. 1984, Jackson et al. 2001, Piehler and Smyth 2011, Grabowski et al. 2012). Thus, many other valuable estuarine species depend either directly or indirectly on oysters. The structured reefs created by oysters also serve as a breakwater for boat and wind-driven waves, helping to protect coastal habitats, such as marshes, and prevent erosion of coastal property (Meyer et al. 1997, Piazza et al. 2005, Scyphers et al. 2011). The economic values associated with these oyster services are substantial, ranging from $10,325 to $99,421 per hectare annually (Grabowski et al. 2012).

Estuaries are also heavily impacted by multiple human and environmental stressors (Lotze et al. 2006). For example, oyster reefs have declined in abundance worldwide due to a range of stressors, including hydrological changes such as flow diversions, increases in disease associated with changing salinity and temperature, pollution, and habitat degradation especially by destructive and excessive harvesting practices (Lenihan and Peterson 1998, Lotze et al. 2006, Beck et al. 2011, Zu Ermgassen et al. 2012). Due to both the importance of oysters as a fishery and their critical role in ecosystem services to the broader ecosystem, oyster fishery management (including harvesting regulations, oyster aquaculture, and restoration of natural reefs) is essential to estuarine management and conservation. However, neither the relative contribution of natural reefs vs. aquaculture practices (including on- or off-bottom oyster production) to ecosystem services, nor their relative susceptibility to common stressors, have been evaluated in many regions of historically high oyster production like the U.S. Gulf of Mexico. Furthermore, the potential for a combination of these methods to enhance the stability of oyster production and related ecosystem services such as water quality and habitat provision is unknown.

In addition to providing a vast array of ecosystem services, oyster reefs also represent a valuable economic and cultural resource in many coastal societies, creating an ideal SES for studying the interplay of resource management, ecosystem services, and human well-being. Thus, understanding the effects of the global decline of oyster reef habitat (Beck et al. 2011) involves consideration of both the ecological and social implications of the loss of a key foundation species and important fishery resource. Balancing societal needs and priorities with ecologically sustainable practices requires support from and involvement of local communities. For ecosystem engineering species like oysters that are also harvested as fisheries, a better understanding of societal values, beliefs, and norms is essential for optimizing the ecosystem services provided by oyster

reefs and addressing the causes and consequences of oyster decline (Scyphers et al. 2014).

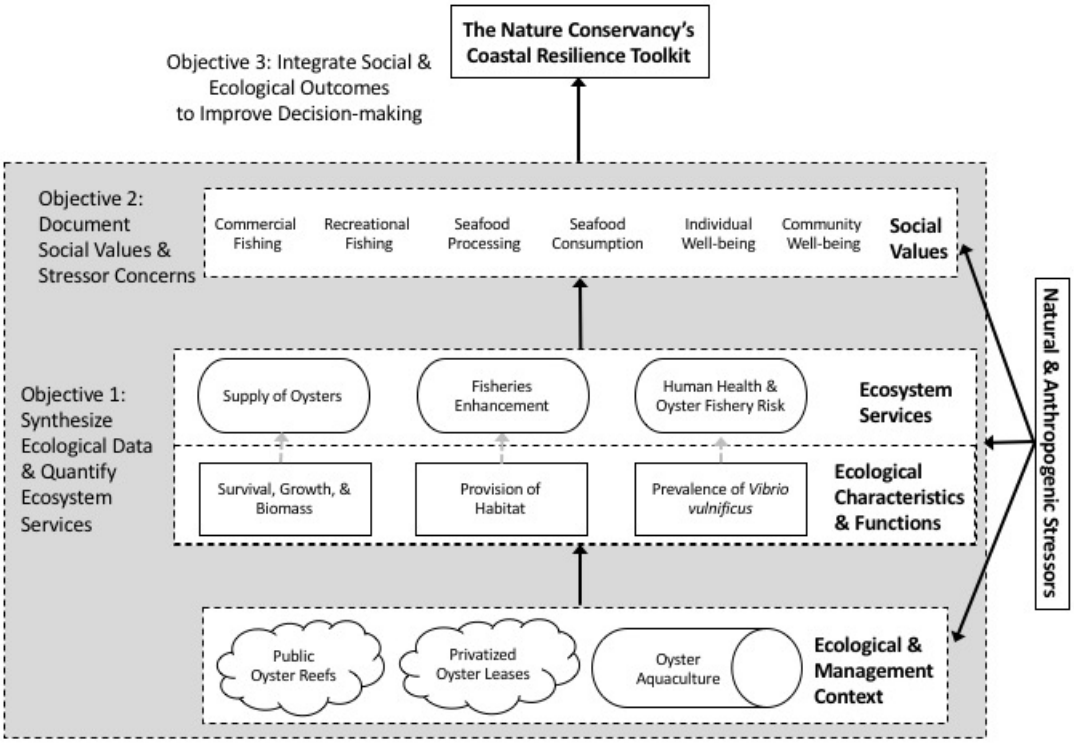


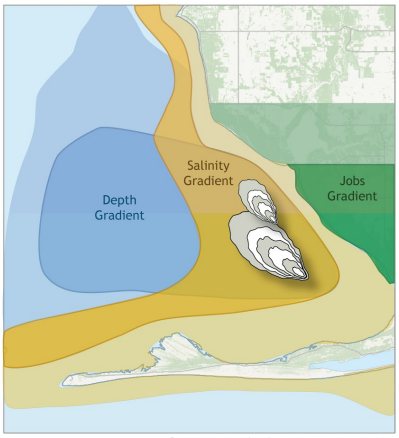
Figure 2. Overview of Proposed Study and Key Objectives

Objectives

Our proposed research will evaluate the ecosystem services provided by oyster habitat in three management contexts (public, natural oyster reefs, private, on-bottom oyster leases, and private, off-bottom aquaculture practices), the social values attached to these services, and the potential for the diversification of the fishery to enhance social and ecological sustainability in response to multiple stressors (Fig. 2). In **Objective 1**, we will synthesize existing ecological data on the ecosystem services provided by oyster reefs globally (e.g., Beck et al. 2011, Grabowski et al. 2012, Zu Ermgassen et al. 2012) and compare them to existing and new (to be generated by our proposed research) data in our focal estuary, Apalachicola Bay, Florida. These data will inform management of the vital oyster fishery in Apalachicola by assessing critical ecosystem services, including the quantity and quality (i.e., physical characteristics and appearance) of the oyster supply, the potential for enhancement of associated fisheries, and the relative risk to human health from diseases like *Vibrio*. In **Objective 2**, we will document social values, beliefs, and norms in the coastal communities of Apalachicola Bay by combining a survey assessing the value of commercial and recreational fishing, seafood processing and consumption, and individual and community well-being with in-person, follow-up interviews, and focus groups at Franklin's Promise, a community coalition that serves to improve residents' quality of life and advocate for the Apalachicola Bay community in Franklin County. Specifically, the surveys and focus groups will assess societal beliefs and values on the importance of oyster ecosystem services, current status and trajectory of oyster populations, major causes of oyster decline, risk perception of threats to human

health and well-being associated with oyster consumption, and support or perceived effectiveness of stewardship initiatives including habitat restoration, reef privatization, and off-bottom aquaculture. In **Objective 3**, we will integrate the data collected in objectives 1 and 2 on social values and ecosystem services of different oyster management contexts to inform decision making and management strategies in Apalachicola Bay via The Nature Conservancy's Coastal Resilience online mapping resource in the Gulf of Mexico (http://maps.coastalresilience.org/gulfmex), a valuable decision support tool that facilitates restoration and recovery planning to maximize the utility of existing environmental, societal, and economic information. This tool, including a specific web app called Restoration Explorer (Fig. 3), explicitly addresses how communities can integrate ecosystem services with human health and well-being to inform their decision making and management practices.

The Restoration Explorer allows stakeholders to examine ecological and socio-economic factors for restoration suitability. In this app an oyster reef index was compiled for restoration scenario planning where individual factors can be weighted for importance when identifying potential restoration sites.



Oysters require specific depth and salinity gradients to ensure restoration success. They also require other factors, here including coastal-based job dependency. The oyster icon indicates an area where both favorable ecological and socio-economic factors align.

Figure 3. TNC's Restoration Explorer web app

Case Study: Apalachicola Bay, Florida

Apalachicola Bay and the surrounding watershed is one of the five richest biodiversity hotspots in North America. In addition to the unique biota of this region, Apalachicola Bay itself is one of the most productive estuarine ecosystems along the U.S. Gulf coast (Montagna et al. 2013), ranking within the top 50 U.S. ports by landings revenue in 2006 (NMFS 2006). Apalachicola Bay also supports a vibrant and unique human community characterized by low development, protected lands, and high attachment to and dependence on local natural resources. However, several of the communities near Apalachicola have socially vulnerable populations with high levels of poverty, lower levels of educational attainment, and generally low diversity of occupational opportunities. For instance, the widely renowned fishing community of Apalachicola had a poverty level of 21.5% in 2013, much higher than the national average of 14.5% (2013 U.S. Census [5-year estimates]).

In Apalachicola Bay communities, fishing is a traditional way of life, with a high reliance on the oyster fishery in particular: oysters provided 42% of the value of all fisheries in Apalachicola in 2012 (NOAA 2015). An estimated 2000 fishers made a living from oyster fishing in 2012 (FWCC 2013). The oyster fishery itself is unique, characterized by non-mechanized harvest of oysters by individual fishermen using hand tongs. Tonging causes less oyster reef degradation, as measured by decline in reef height after harvesting, than dredging behind motorized fishing boats (Lenihan and Peterson 2004). Apalachicola oysters are a recognized commodity throughout the state and the nation. Although Apalachicola is the smallest fishing community in West Florida by population, it has historically provided 90% of the total oyster catch in Florida, and 10% of the catch nationwide (Berrigan 1990, Wilber 1992, Livingston et al. 2000).

Public oyster reefs cover approximately 10% of the bottom of Apalachicola Bay (Niu et al. 1998), and research on these reefs dates back to the late 1800s (c.f., Swift 1896, Danglade 1916). In Apalachicola Bay, oysters grow continuously throughout the year, reaching marketable harvest size in approximately 18 months, considerably faster than more northerly oyster populations (Ingle 1951, Ingle and Dawson 1953). Oyster demographic rates (growth, reproduction, survival) are dependent on a range of abiotic and biotic environmental factors, including temperature, salinity, food availability, sedimentation, predation, disease, pollution, harvesting, and physical disturbance (Levinton 2013), and changing environmental conditions may represent significant stressors on the stability and function of the oyster ecosystem and associated fishery. Of these, oysters are particularly sensitive to changes in salinity because of its relation to other factors such as food availability, disease, and predation (Copeland 1966, Christensen et al. 1998, Livingston et al. 2000, Powell et al. 2003, Wang et al. 2008). Oyster tolerance to both higher and lower salinities is negatively correlated with water temperature: as water temperatures increase, tolerance decreases (Quast et al. 1988, Hofstetter 1990). In addition, both temperature and salinity influence prevalence of *Vibrio vulnificus*, a human pathogen that is frequently associated with Gulf Coast oysters and represents a potentially serious human health risk (Motes et al. 1998, Froelich and Oliver 2013).

Although the abundance of oysters and reef area have declined in many estuaries and led to precipitous declines in oyster fisheries (Lotze et al. 2006, Beck et al. 2011), oyster populations in Apalachicola and the broader northern Gulf of Mexico region remained relatively intact through 2010, declining the least and maintaining the highest catch of wild oysters in the world (Beck et al. 2011). In addition, Apalachicola Bay was one of only 2 U.S. estuaries estimated to have stable oyster biomass when comparing recent years (2000-2010) to a baseline in 1900, in contrast to temperate estuaries elsewhere (Zu Ermgassen et al. 2012).

However, this historically high productivity, and the dependent fishery, declined dramatically in 2012. From September 2012 through February 2013, commercial harvest revenues declined by 43% and commercially marketed pounds of oyster meats declined by 58%. These declines in the fishery reflected the unprecedented poor quality of the reefs themselves, which exhibited a decline of 80% in oyster biomass (>25 mm in length) and of 67% of legal-sized oysters on major reefs (FWCC 2013). The ecosystem services provided by oysters have undoubtedly also declined, and the Apalachicola community has suffered as a result. In fact, the U.S. Secretary of Commerce declared a “Commercial Fishery Failure” in August 2013, indicating the dramatic nature of the fishery decline and high dependence and vulnerability of Apalachicola Bay fishing communities.

Historically, harvesting of wild-caught oysters on public reefs has formed the basis of the oyster fishery in Apalachicola, but the recent decline in commercial harvest revenue and adult oyster biomass due to the effects of multiple stressors has prompted interest in alternative approaches to protect and restore the ecosystem services provided by oyster reefs and to ensure the health and well-being of the Apalachicola community in the long-term. Despite the widespread use of oyster aquaculture on the West Coast for the Pacific oyster and on the East Coast for the Eastern oyster, the potential for aquaculture as a sustainable solution to the decline of the oyster in the Gulf of Mexico regionally and in Apalachicola Bay locally has remained largely unexplored.

Private, on-bottom oyster leases have existed in Franklin County and surrounding waters since the 1800s, but approval for new leases, and in particular, off-bottom farming practices, were granted in 2013 in both Franklin and adjacent Wakulla County. In 2016, Gov. Rick Scott approved FL Senate Bill 1318, upending the long-standing requirement that all oysters in Apalachicola Bay be harvested with hand tongs, allowing for mechanical harvesting of oysters on some private leases in Apalachicola Bay. Assessing the capacity for oyster aquaculture to sustain ecosystem function and afford ecosystem services is vital in development and application of these alternative techniques. Further, the effectiveness of different practices, such as the privatization of the fishery with oyster leases and aquaculture farming, depends on a number of ecological and societal factors. Because the oyster fishery is deeply embedded in a complex social-ecological system, assessing economic potential, human health impacts, and stakeholder support (including that of local practitioners, resource managers, and consumers) for different practices is as important to predicting the success and sustainability of aquaculture as measuring the capacity for private leases and farming techniques to provide ecological functions and sustain ecosystem function.

We will evaluate the public health impacts, societal perceptions of, and ecosystem services provided by oysters in three distinct management contexts: (1) public, natural oyster reefs; (2) private oyster leases using on-bottom culture and harvest; and (3) private oyster leases using off-bottom culture (e.g., floating bags) and harvest. These contexts are spatially segregated from one another, with public reefs located primarily subtidally throughout Apalachicola Bay, and private leases distributed along the shallows on the western side (St. Vincent Sound). The off-bottom aquaculture leases are further spatially separated by occurring in the water column rather than the benthos. We hypothesize that stressors will be similarly decoupled: for example, outbreaks of the human pathogen *Vibrio* may be more likely in the warmer, surface waters of off-bottom cultures compared to on-bottom leases and public reefs, whereas stresses from high salinity and marine predators are more likely in saline bottom waters.

Considering the importance of oysters as a fisheries resource, the diverse ecosystem services provided by reefs, and the multitude of natural and anthropogenic stressors responsible for population declines, achieving long-term sustainability within this SES will require societal support for alternative management strategies and/or continued investment in stewardship initiatives (Scyphers et al. 2014). Diversification of the oyster fishery, promoted by the expansion of aquaculture across multiple, decoupled management contexts, may increase the stability of oyster production and associated ecosystem services (c.f. Schindler et al. 2010), but only if the local community is supportive of and equitably benefits from these efforts. The oyster fisheries of Apalachicola provide an ideal SES for examining management strategies to enhance resilience of coastal ecosystems and human societies and promote human health and well-being.

Approach and Activities

Question 1: What are the factors that determine success or failure, when using existing data sources on environmental pollution, ecosystem services and community health and well-being, to understand the impacts of multiple stressors?

Objective 1*: Synthesize Ecological Data and Quantify Ecosystem Services*

Approach: We will synthesize existing ecological data on the ecosystem services provided by oyster reefs globally and compare the results to (1) long-term data on public, natural oyster reefs in Apalachicola Bay, FL, and (2) new data assessing the relative contribution of different oyster management contexts (e.g., public, natural reefs and privatized leases employing different aquaculture methods such as on-bottom versus off-bottom culturing) to ecosystem services in Apalachicola Bay, FL.

Activities: The focus of our study is the sustainability and resilience of the Apalachicola oyster fishery, including assessment of the ecosystem services provided by different oyster management strategies and the resultant effects on the health and well-being of the Apalachicola community. To place our detailed assessment of ecosystem services and the social-ecological coupling in this coastal society in a broad context and to compare it to provision of ecosystem services globally, we will synthesize data from existing studies assessing ecosystem services provided by oyster reefs historically and currently (e.g., Beck et al. 2011, Grabowksi et al. 2012, Zu Ermgassen et al. 2012). The synthesis will include assessment of environmental and anthropogenic stressors affecting oyster reefs, such as overfishing, habitat loss, disease, and changes in salinity (Beck et al. 2011), as well as the provision of ecosystem services such as oyster production, water filtration, habitat provision, carbon sequestration, shoreline stabilization, and landscape diversification (Grabowski and Peterson 2007). In addition, we will assess historic and current, and actual and perceived, risks to human health and well-being from the shellfish-born pathogen, *Vibrio vulnificus*, nationally and regionally (Motes et al. 1998, Morgan et al. 2009, Froelich and Oliver 2013).

Monitoring activity	Metric relevant to proposed research	Data Source	Time series	Locations
Oyster growth	Oyster production	ANERR	2004–present	Dry Bar & Cat Point commercial oyster reefs
Oyster recruitment	Oyster production	ANERR	2004–present	Dry Bar & Cat Point commercial oyster reefs
Water Quality (data loggers)	Environmental conditions	ANERR	1992–present	Dry Bar & Cat Point commercial oyster reefs
Water Quality (point samples of chl *a* and nutrients)	Environmental conditions	ANERR	1992–present	11 sites throughout Apalachicola Bay
Monthly trawls of fish & macro-invertebrates	Associated fisheries production	ANERR	2000–present	12 sites throughout Apalachicola Bay
Seasonal stock assessment of commercial oyster reefs	Oyster production	FDACS	1989–present	Dry Bar & Cat Point commercial oyster reefs
Monthly dockside oyster landings	Oyster production	FWCC	1990–present	Dry Bar & Cat Point commercial oyster reefs

Table 1. List of available data that will be synthesized to quantify variability in the functioning and services provided by natural oyster reefs in Apalachicola Bay, FL. Environmental data on water quality are also available and will be used to interpret abiotic causes for variability in oyster reef functioning. Data collected by the Apalachicola National Estuarine Research Reserve (ANERR) are housed at

http://www.dep.state.fl.us/coastal/sites/apalachicola/science/. Data provided by the Florida Fish and Wildlife Conservation Commission (FWCC) are housed at http://myfwc.com/research/saltwater/fishstats/commercial-fisheries/landings-in-florida/. Data collected by the Florida Department of Agriculture and Consumer Services (FDACS) are available by request.

To compare broad patterns identified in the synthesis with recent and current provision of ecosystem services by Apalachicola oyster reefs, we will take advantage of the extensive environmental and monitoring data collected by the Apalachicola National Estuarine Research Reserve (ANERR) and detailed data on oyster growth and landings from the Florida Fish and Wildlife Conservation Commission (FWCC) and the Florida Department of Agriculture and Consumer Services (FDACS; see Table 1). To assess oyster growth and biomass, we will use existing data from (1) ANERR's oyster growth monitoring project; (2) FDACS's seasonal stock assessment; and (3) FWCC's monthly dockside landing monitoring to determine historic and current rates of oyster growth in different sites in the bay (Table 1). In addition, ANERR has monitored recruitment rate (i.e., spatfall data) since 2004 across Apalachicola Bay; we will use this information to look at oyster population stability and the capacity for recovery. To relate oyster growth and recruitment to water quality across Apalachicola Bay, we will use ANERR's daily data on temperature, salinity, dissolved oxygen, pH, and turbidity, and monthly data on nutrient availability and chlorophyll *a* content. To assess habitat provision, we will use data from ANERR's monthly trawling surveys across Apalachicola Bay. By pairing detailed data on the occurrence and abundance of fish and invertebrate species with oyster growth and biomass data and environmental and water quality data, we will be able to assess temporal variation in oyster reef productivity within Apalachicola Bay and the effects on associated ecosystem functions and services.

We will also collect new data on ecosystem services across a range of oyster management contexts in Apalachicola Bay. Specifically, we will sample 5 natural, public reefs, and 10 private oyster leases, 5 of which employ on-bottom and 5 of which employ off-bottom methods of oyster aquaculture. The public reefs will be chosen based on our prior experience in Apalachicola Bay and with input from local practitioners via our collaboration with consultant Joe Taylor (see letter of intent from Franklin's Promise), executive director of Franklin's Promise, a community coalition that serves to improve residents' quality of life and advocate for the Apalachicola Bay community. Tommy Ward, owner of 13 Mile Seafood in Apalachicola, has agreed to provide access to his lease for sampling and to facilitate connections with leaseholders in Apalachicola Bay for the identification of additional leases using on-bottom and off-bottom farming practices.

In years 1 and 2, we will monitor the 15 sites monthly during the peak growing season (April-October) and once during the colder months (January) for a total of 8 sampling dates per year. The public reefs will be sampled by boat, building on our partnership with Joe Taylor and Franklin's Promise to identify local fishers willing to provide site access in return for paid reimbursement for their time. The community partners (e.g., Tommy Ward and lease owners) will also be reimbursed for all oysters they collect for this study. To assess habitat provision and the capacity for fisheries enhancement (*ecosystem service I*) associated with each of the oyster management contexts (i.e., public, natural reefs, private, on-bottom leases, and private, off-bottom aquaculture), we will trawl our sites using methods similar to the ANERR protocol (i.e., 5 two-minute tows) on each sampling date. Fish and invertebrate species will be identified

and enumerated, and the first 20 individuals of each species will be measured; they will then be released. To assess environmental conditions and identify potential stressors, we will measure temperature, salinity, dissolved oxygen, pH, and depth at each site.

To assess oyster production (*ecosystem service II*) at each site, we will measure the size, age, and condition of 30 oysters (5 individuals randomly sampled from 6 quadrats, cages, bags, etc. at each site) on each sampling date to determine oyster growth and biomass. In addition, we will assess physical characteristics and general appearance of sampled oysters, which may greatly affect consumer demand and economic value. Specifically, we will quantify the number of mud blisters and worm burrows on each shell (caused by the mud blister worm *Polydora sp.*) and the proportion of shell infected with the boring sponge *Cliona celata*, both of which have resulted in significant economic losses from wild-harvested and farmed oysters as a result of decreased aesthetic appeal, weakened shell condition, and increased sulfurous odor (Nel et al. 1996, Carver et al. 2010). While off-bottom culture techniques may decrease boring sponge prevalence compared to natural reefs or on-bottom farming methods since infection occurs primarily through direct contact with *Cliona* on the substrate (Rosell et al. 1999), oysters cultured off-bottom may have greater mud blister worm infestation than wild-harvested oysters or oysters cultured on-bottom because off-bottom practices allow the mud blister worm to escape predation (Nel et al. 1996).

In addition to oyster parasites, we will quantify the threat due to the human pathogen *Vibrio* that occurs in shellfish and estuarine waters and is the leading cause of deaths associated with the consumption of raw or undercooked shellfish (Oliver 2005). *Vibrio* is particularly prevalent in oysters, which may harbor high concentrations of the bacteria (Motes et al. 1998). In the United States, the incidence of vibriosis increased from 1996-2010 (Newton et al. 2012), and the mortality rate of cases resulting in septicemia is around 50% (Motes et al. 1998, Oliver 2005). Historically, Apalachicola Bay has been one of the source sites of oysters frequently associated with *Vibrio* outbreaks in the Gulf Coast (Motes et al. 1998); thus, it's critical to assess current concentrations of *Vibrio* in this region for each oyster management context. We will assess prevalence and intensity (i.e., concentration) of the bacteria *Vibrio vulnificus* using quantitative PCR (qPCR). The benefits of qPCR, compared to traditional methods, include increased sensitivity (i.e., the ability to detect low concentrations of *Vibrio*) and the development of species-specific assays that facilitate differentiation and quantification of individual *Vibrio* spp. (Staley et al. 2013). Using the qPCR assay developed by Campbell and Wright (2003), which has been tested and optimized by Wright et al. (2007) and Staley et al. (2013), we will assess *Vibrio* prevalence and bacterial concentrations at each of our sites in Apalachicola Bay during the first and second year of our study to determine the current risk to human health and well-being in this region and to compare *Vibrio* prevalence in natural reefs, on-bottom leases, and off-bottom aquaculture practices (*ecosystem service III*).

Analysis: Because *Vibrio* sampling will be paired with environmental data, we will be able to assess the relationships between bacterial concentrations and stressors such as temperature and salinity, as well as identify potential drivers of variation in prevalence of this harmful pathogen across oyster management contexts in Apalachicola Bay. We will also compare public awareness of *Vibrio* and concern with pathogen infection and exposure (see *Objective 2*) with current levels of risk. In addition, we will

use generalized linear models to examine relationships between environmental variables and ecological characteristics, and to compare the provision of ecosystem services by each oyster management context.

Question 2: What are the factors that influence whether and how transparent decision making processes are developed and used to identify the most important stakeholders and stressors, evaluate management strategies and set and prioritize goals?

Objective 2*: Conduct Socioeconomic Surveys & Organize Stakeholder Focus Groups to Document Social Values & Concerns*

Approach: To assess the social values and concerns of coastal residents and key stakeholders (e.g., oyster harvesters, seafood processors, etc.), we will conduct societal-level surveys and targeted stakeholder focus groups. This will address two key livability principles, valuing and supporting the existing community and enhancing the unique characteristics of the community, by developing a plan to promote the health, resilience, and sustainability of the Apalachicola Bay oyster fishery and the people that rely on this tightly coupled social-ecological system. First, we will conduct a mixed-mode survey of coastal residents to document their attitudes, beliefs, concerns, and values regarding oysters, coastal ecosystems, and stressors. Second, we will partner with a local community organization (Franklin's Promise) to conduct a series of interviews and focus groups involving key stakeholder groups unlikely to be adequately represented in the broader survey.

Activities: We will recruit survey participants across a three county region (Gulf, Franklin, Wakulla) using address-based sampling and mailed survey invitations. The physical addresses of residents will be acquired using U.S. Postal Service data and ZIP+4 targeting, and survey invitations will be sent as postcards featuring a web address and unique password to access the survey. We will use pre-notifications, incentives, and reminders to enhance survey response rates. Additionally, printed surveys will be mailed to a subsample of 20% and all potential respondents who request it. Qualtrics Survey Research Suite will be used to design, host, and recruit panel participants. All survey data will be georeferenced at the parcel or census block level to allow spatial modeling. These surveys will build upon our previous work on residential shoreline management in coastal AL and ongoing efforts in AL, FL, NC and RI. Previous survey of AL and FL (Pensacola Bay area) coastal residents had responses rates of at least 20% and up to 36% across all subgroups (Scyphers et al. 2014, 2015, In Revision). Based upon these response response rates and a mailing of 2,000 surveys, we expect a sample size of at least 400. The key themes of the survey will be: 1) perceptions of oyster population and fishery status, 2) values associated with oyster harvest and ecosystem services, 3) ecological concerns associated with oyster population and fisheries declines, and 4) risk perceptions and preferences associated with oyster consumption (linked to *Objective 1* insights on prevalence of *Vibrio vulnificus* and overall oyster quality, including appearance and taste).

Focus groups will be convened with key stakeholder groups in each year of the project, organized by Franklin's Promise. Additional in-person interviews will be conducted to follow up on the surveys, particularly with community members under-represented in the survey. We anticipate 10-15 participants per focus group, who will be recruited to reflect diverse attitudes towards oyster management, restoration, and

aquaculture. The first set of focus groups will likely be comprised of participants from within the same stakeholder group (e.g., recreational fishers), while the second and third will involve a different group of individuals representing various stakeholder interests. We expect each focus group will take 2-4 hours. During each focus group, we will present data collected from surveys to construct concept maps of common knowledge and beliefs representing each stakeholder group, or perspectives of those participating in the focus group using the concept mapping tool Mental Modeler (www.mentalmodeler.com). At each focus group, respondents will first have an opportunity to view and revise a concept map representative of their functional role and personal knowledge and beliefs. Specifically, these concept maps will consist of the important concepts (i.e., variables or nodes) comprising the oyster fishery SES connected by directional arrows and an indicator of relative influence. The final portion of the focus groups will involve using Mental Modeler to visualize potential scenarios of oyster management (aligned with *Objective 1* above) focusing on both historical and hypothetical future scenarios of environmental change and policy. After each scenario, we will briefly survey participants on their perception of the outcome for marine ecosystems, as well as their personal fishing satisfaction and livelihoods.

All survey data will be collected under the auspices of Northeastern University's Institutional Review Board. Scyphers currently has active IRB protocols for ongoing surveys of coastal residents and recreational and commercial fishers (Protocols #12-05-17, #12-07-25, #12-11-25). For all data collection, our survey instrument and methodology will be adapted with local stakeholders' and fisheries managers' input and designed to allow comparisons with our previous and ongoing efforts. In addition to the core sections, the survey instrument will also collect demographic information and determine the respondent's dependence on coastal resources for use in analyses.

Analysis: Survey responses will be compiled and analyzed in the Statistical Package for the Social Sciences (SPSS v21). Questions with categorical and nominal responses will be analyzed using traditional univariate and multivariate statistical approaches including decision trees and logistical regression models. Mental model data will be analyzed using standard network statistics (N concepts, N connections, centrality, etc.). Qualitative and open-ended responses will be coded and analyzed using DeDoose software.

Question 3: What are the most effective methods for tracking progress and ensuring accountability towards mitigating and reducing adverse impacts to ecosystems and human health and well-being at the community level?

Objective 3*: Integrate Social and Ecological Outcomes to Improve Decision Making*

Approach: We will partner with The Nature Conservancy (TNC) to incorporate our detailed data on social values and ecosystem services in northwest Florida into their widely used Coastal Resilience decision support tool and Restoration Explorer web app (http://goo.gl/ikCT2x; Fig. 4). We will update the tool with information gathered and processed in *Objective 1*, create new site-level data with social attributes in *Objective 2*, and generate a new web app on the Coastal Resilience tool platform. Specifically, we will modify the existing Restoration Explorer web app and refine it into a "Management Effectiveness" web app to assess the potential for oyster restoration and aquaculture in Apalachicola Bay, a region of high priority in the Gulf of Mexico, to achieve locally desired social and ecological outcomes.

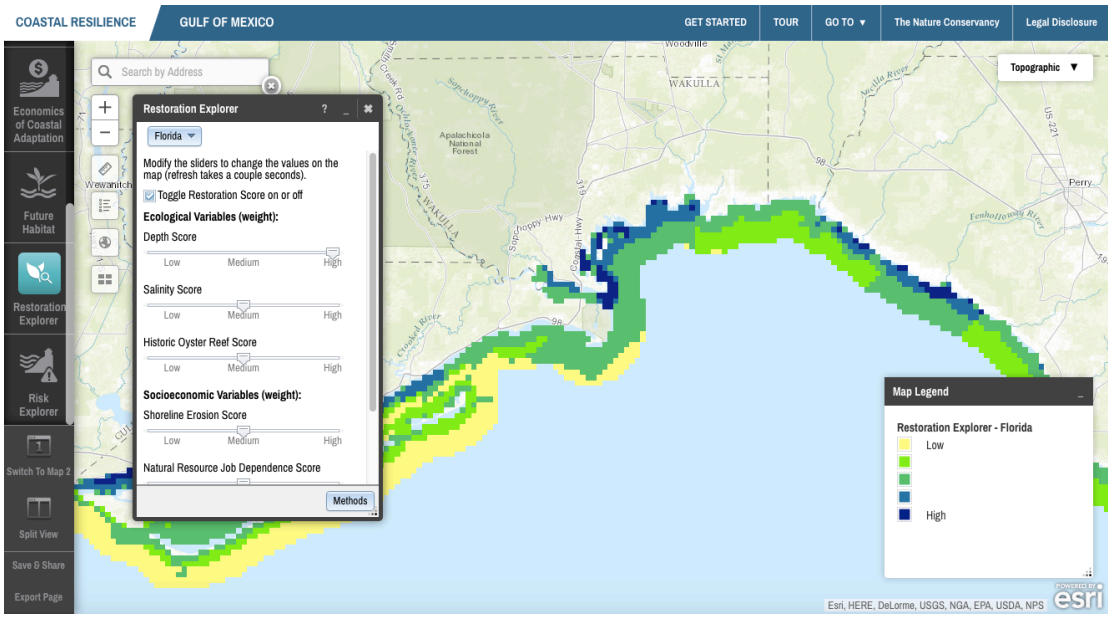


Figure 4. TNC's Restoration Explorer web interface allows the identification of the areas most suited to oyster restoration based on weighted ecological and socioeconomic criteria. The data generated by this project would facilitate the incorporation of spatially explicit data on social values and beliefs and ecosystem services provided by diverse management contexts into planning in Apalachicola Bay, FL.

Activities: TNC has developed the Coastal Resilience Gulf of Mexico project (http://coastalresilience.org/project-areas/gulf-of-mexico/) and online web mapping tool, complete with a robust Gulf Coast spatial database to help facilitate restoration and recovery decisions, and to inform the identification of oyster reef restoration projects with maximum ecological, social, and economic benefits. The Oyster Restoration Explorer facilitates scenario planning by allowing the user to assign weights to a variety of criteria and suitability parameters, including ecological characteristics, such as salinity, depth, and historic productivity, and social and economic criteria, such as vulnerability to shoreline erosion and community dependence on the health of coastal natural resources. Our project will provide important data on social values within coastal communities, such as site-scale cultural reliance on commercial and recreational fishing, and seafood processing and consumption for overall individual identities and community well-being. Incorporation of our data on ecosystem services provided by oyster reefs, such as the quantity and quality (i.e., taste, appearance, etc.) of oysters produced, the relative enhancement of associated fisheries, and the potential risk to human health and the oyster fishery from diseases like *Vibrio*, will greatly enhance this decision support tool.

Working with TNC, we will assemble and analyze social and ecological data and incorporate them into a new "Management Effectiveness" (ME) planning web app, further refining the Restoration Explorer app, and thereby enhancing the Coastal Resilience tool. The ME app will allow planners to draw spatially-explicit social-ecological relationships to visualize and analyze community risks in the local planning context, while illustrating potential restoration and adaptation solutions using a variety of oyster management strategies. The ME app will be designed so the end users can utilize a "sliding scale of effectiveness" approach, where individual indicators can be weighted for importance relative to other indicators. The ME app will also be designed to identify

oyster reef restoration and aquaculture areas that most benefit socially vulnerable and resource-dependent communities. After year one of the project, we will conduct a first round of Coastal Resilience and ME app usability testing to gather feedback and incorporate it into the final app development phase. We will conduct a training workshop that includes usability testing with key stakeholders to ensure maximum ease-of-use when using and applying the tool to local planning processes. Additionally, we will prepare and disseminate a project fact sheet that highlights the process, successes, and challenges of using the existing communication networks. We also plan to share information on the process, data needs, and community successes with other communities and practitioners across the Gulf of Mexico. Once the ME app and enhanced Coastal Resilience tool are complete, we intend to provide subsequent outreach and training via a webinar series.

Innovation and Sustainability

Our research will develop and promote innovative and sustainable solutions to benefit the environment and strengthen the health and well-being of the Apalachicola community. Specifically, we will promote **environmental sustainability** by evaluating the oyster management context that maximizes multiple ecosystem services. In addition, we will address **social sustainability** by determining which of these management contexts minimizes the exposure of both oysters and humans to the pathogen *Vibrio*, which poses a threat to human health. We will further enhance **social and economic sustainability** by promoting effective restoration planning and sustainable practices through the Coastal Resilience tool and ME web app. The Coastal Resilience program is a public-private partnership led by The Nature Conservancy dedicated to protecting coastal social and ecological communities. The program consists of an approach, a web mapping tool, and a network of practitioners around the world supporting hazard mitigation and climate adaptation planning. The approach consists of four critical steps: (1) **Assess Risk and Vulnerability** to coastal hazards including current and future storms and sea level rise; (2) **Identify Solutions** for reducing risk across social, economic, and ecological systems; (3) **Take Action** at priority conservation and restoration sites to help communities identify and implement nature-based risk reduction solutions; and (4) **Measure Effectiveness** to ensure that efforts to reduce risk while increasing community and ecosystem resilience are successful. Coastal Resilience projects have applied this approach around the U.S., encompassing 17 coastal states, in the Caribbean, across Mexico and Central America, and a global effort enables planners, government officials, and communities to develop risk reduction, restoration, and resilience strategies.

The novel mechanism for linking the Coastal Resilience approach with on the ground projects is through the decision support tool (http://maps.coastalresilience.org). A network of Coastal Resilience practitioners has trained and supported over 100 communities around the world on the uses and applications of the tool, focusing on the identification of nature-based adaptation and risk mitigation solutions. Within the tool, web apps customized to meet specific planning needs are designed and implemented. Web apps are designed to target key audiences for decision-making, as well as users that can inform those key decision makers. The tool and web apps include tracking analytics to monitor where and how often users are accessing the information. This information is used to make the web apps as effective as possible towards supporting nature-based and coastal hazard decisions.

The work we propose here is to conduct a target audience and user assessment of the tool and further customize the Restoration Explorer towards a Management Effectiveness web app to identify oyster restoration projects at the site scale that meet social, economic, and ecological needs. Combining spatially-explicit data (*Objective 1*) with results of community surveys (*Objective 2*) will allow us to track and monitor scientific information with community attitudes, beliefs, concerns, and values regarding oysters, coastal ecosystems, and stressors over time.

Expected Results and Outcomes

(1) Our synthesis and analysis of ecosystem services provided by oysters from different management contexts will provide critical information regarding the role of on-bottom and off-bottom aquaculture practices relative to natural, public reefs. *Ultimately, this information will be used to determine the ecosystem, societal, and economic benefits of improved environmental management and their effects on the health and well-being of the Apalachicola community.* In addition, it will inform several Research Priorities identified in the 2015 Florida Aquaculture Plan, including: compare techniques to prevent and control bio-fouling of shellfish; develop disease surveillance and health management strategies for cultured oysters; and improve the understanding of shellfish farm environmental interactions concerning carrying capacity, water quality, and benthic soils. (2) Our mixed-mode survey will *identify the factors that influence the communities' awareness and appreciation of oyster ecosystem services, and perception of risk and preferences associated with oyster consumption, so that information can be used in setting priorities.* (3) Our social-ecological survey combined with our ecosystem service data across different oyster management contexts will *highlight the factors influencing adoption of behaviors, and the effectiveness of those behaviors, to protect the environment and sustain the oyster fishery*. By integrating our results into the ME web app, we will produce a valuable decision support tool for using existing ecological and human health data to inform and prioritize environmental protection via oyster restoration.

Project Management

Personnel: This project involves a collaboration among PIs and a Postdoc at Northeastern University (NEU: Hughes, Scyphers, Hanley), Franklin's Promise (Taylor), and The Nature Conservancy (Ferdana). All NEU personnel will make at least one trip per year to Apalachicola, FL to implement the social surveys and field ecological sampling. In addition, the NEU-funded Masters and undergraduate students will live in Apalachicola for the duration of their positions to conduct the surveys and sampling. This project will also benefit from continued collaboration with Mr. Tommy Ward of 13 Mile Seafood in Apalachicola, who will provide access to his oyster lease and facilitate connections with other leaseholders.

Lead PI Hughes (Assistant Professor) will oversee all aspects of the project, coordinating the social and ecological research and advising personnel. She will also lead the ecological synthesis, analysis, and new data collection. PI Hughes is experienced with data synthesis and meta-analysis, having led several previous synthesis projects (Hughes et al. 2004, 2007, 2009). She also has over 15 years experience in oyster reef ecology, including in Apalachicola and surrounding waters (e.g., Grabowski et al. 2005, Hughes and Grabowski 2006, Hughes et al. 2012, Kimbro et al. 2014).

PI Scyphers (Associate Research Scientist) will lead the socioeconomic surveys, interviews, and focus groups. Scyphers is experienced with survey design and analysis, having led several previous projects on the values, beliefs, and attitudes of coastal residents and fishers (e.g., Scyphers et al. 2014, 2015). He has over 8 years of experience in the coastal communities and ecosystems of the northern Gulf of Mexico.

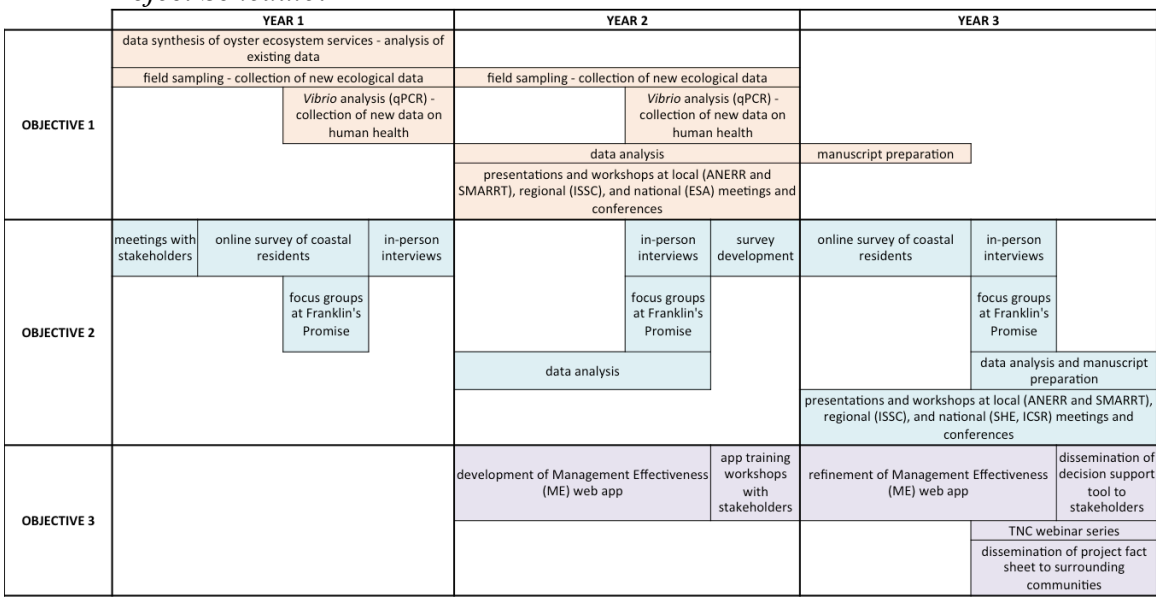
Postdoc Hanley will lead the processing of oyster samples at the NEU Marine Science Center (MSC) for growth, biomass, shell condition, and the prevalence of *Vibrio vulnificus* using quantitative PCR (qPCR). Dr. Hanley has extensive molecular genetic experience (e.g., DNA extraction, PCR, qPCR, gel electrophoresis, cloning, sequencing, genotyping, etc.) and has designed protocols for genetic analysis of a variety of plant and animal species, including oysters. In addition, she has developed and optimized qPCR assays for multiple oyster diseases, including Dermo and MSX.

Senior Collaborator Ferdana will manage the design and development of the Coastal Resilience tool and Management Effectiveness web app. In collaboration with project leaders at NEU, he will also facilitate app training workshops and dissemination of the decision support tool to resource managers and stakeholders in Apalachicola and surrounding communities via the production of printed materials and online webinars.

Consultant Taylor, Executive Director of Franklin's Promise, will facilitate community interactions and engagement. Franklin's Promise is a critical part of our community engagement plan, helping to coordinate in-person interviews and focus groups. They will also coordinate working relationships with oystermen.

Facilities: The field research will be conducted in Apalachicola, FL. The laboratory research will be conducted at the NEU MSC, a full-service marine laboratory with a computer laboratory, classrooms, laboratories, flow-through seawater, and several general use mesocosm arrays. Dedicated facilities in PI Hughes's lab at Northeastern include standard equipment for DNA extraction and amplification (including PCR and qPCR) and gel electrophoresis, such as a laminar flow hood, a mixer mill, pipettes, heating blocks, vortexes, centrifuges, and thermocyclers, as well as basic laboratory equipment, such as freezers, refrigerators, drying ovens, and balances.

Project Schedule:



QUALITY ASSURANCE STATEMENT

PI Hughes will be responsible for the quality assurance (QA) and quality control (QC) aspects of the research. Hughes (Assistant Professor) has extensive experience collecting field and laboratory data, training and managing project personnel, conducting and coordinating research that requires a high level of QA/QC, and organizing and maintaining large datasets. In addition, all PIs have received training in Environmental Health and Safety, Humane Care and Use of Laboratory Animals, and Responsible Conduct of Research at NEU and all project personnel will receive the same training. The PIs have completed training in the Use of Vertebrate Animals in Instruction or Research and have active protocols with the Institutional Animal Care and Use Committee.

A) Project Objectives

Our proposed research will evaluate ecosystem services provided by oyster habitat in three management contexts, public, natural reefs, private, on-bottom leases, and private, off-bottom aquaculture, the social values attached to these services, and how they respond to multiple stressors. We hypothesize that the diversification of the oyster fishery across these three management contexts will enhance its social and ecological sustainability. In Objective 1, we will synthesize existing ecological data on the ecosystem services provided by oyster reefs globally and compare them to existing and new data in our focal estuary, Apalachicola Bay, FL. In Objective 2, we will document social values, beliefs, and norms in the coastal communities of Apalachicola Bay. In Objective 3, we will integrate the data collected in objectives 1 and 2 on social values and ecosystem services of different oyster management contexts to inform decision-making and management strategies in Apalachicola Bay.

B) Data Collection

B.1) Collection of New/Primary Data

In Objective 1, the collection of new data will be achieved by using accepted methodology (e.g., Environmental Protection Agency (EPA)) to collect and/or measure, analyze and/or interpret data on environmental conditions (e.g., salinity, temperature), oyster production (e.g., growth, condition), and associated ecosystem services (e.g., fisheries enhancement from habitat provision and human health risk from *Vibrio*) at 15 sites in Apalachicola Bay, FL, USA. The field sampling is designed to provide information on the relative contribution of different oyster management contexts to ecosystem services, which will be related to social values and stakeholder needs and priorities. Table 2 lists the data that will be collected. Data QA/QC in the field will include: 1) routine field instrument calibration, which will be performed at least once per day prior to use to ensure that instruments are operating properly and producing accurate and reliable data; 2) labeling of samples with a unique ID number, sample ID, location ID, date, and time; and 3) documenting all field activities and recording any pertinent field information on datasheets. Oysters will be placed in individual plastic bags and set immediately on ice in the field. Following express shipment on dry ice to NEU, samples will be stored at -80^{o}C until sample processing and analysis. *Vibrio* analyses will be conducted using established methodology and standard operating procedures (e.g., Campbell and Wright (2003), Wright et al.

(2007), Staley et al. (2013)), including 1) sterilization of all surfaces and instruments prior to use; 2) preparation of standards, positive controls, and QC checks in a different location than samples; and 3) the use of standards of known concentrations to develop a standard curve with efficiency 90-110% and R^2 > 0.99, positive and negative controls, and additional planned QC checks (e.g., spikes) in every qPCR run. Standards and samples will be run in duplicate to measure sampling precision and variability. If standard curves do not meet the acceptance criteria, the run will be redone. If sample duplicates vary beyond the accepted standard of cycle threshold difference <1, samples will be rerun. In addition, disease data will be validated using traditional direct plating methods (e.g., Tamplin et al. 1991) for a subset of samples.

Table 2. Field sampling design at 15 sites in Apalachicola Bay, FL, including 5 public, natural reefs, 5 private, on-bottom oyster leases, and 5 private, off-bottom aquaculture sites. Sampling will occur 8 times per year, including monthly from April to October during the peak growing season and once in January.

Sample Description	Sample Size	Sampling Methods	Variables Measured
oysters	N=30 per s te	hand tong ng (pub c reefs) from 5 0.25 m^2 quadrats OR purchased from easeho ders (pr vate eases), random y se ected from 5 cages, bags, etc.	s ze, age, growth, b omass, cond t on ndex, mud b ster worm count, bor ng sponge percent cover, *Vibrio* preva ence and concentrat on
f shes	1 traw per s te	traw / catch and re ease	dent f cat on and enumerat on of spec es, measurement of f rst 20 nd v dua s per spec es
macro- nvertebrates	1 traw per s te	traw / catch and re ease	dent f cat on and enumerat on of spec es, measurement of f rst 20 nd v dua s per spec es
env ronmenta cond t ons	5 ocat ons per s te	*in situ* measurement	temperature, pH, d sso ved oxygen, and sa n ty (YSI)

B.2) Use of Existing/Secondary Data

In Objective 1, existing/secondary data will be extracted from published, peer-reviewed studies for synthesis of the ecosystem services provided by oyster reefs globally, including effects on the health and well-being of coastal communities. The synthesis will include an exhaustive search of studies published before December 2016 in Google Scholar and Web of Science (ISI) using a targeted keyword search. In addition, we will also target reviews and meta-analyses on the topic (e.g., Beck et al. 2011, Grabowksi et al. 2012, Zu Ermgassen et al. 2012), checking both the literature cited in each paper and the studies subsequently citing each paper and extracting any relevant data for synthesis and analysis. The information recorded and data extracted from each study will include: location and date of the study, units of measurement (including accuracy, average, and standard error), and replication. Data management will include a study database of all extracted data that is backed up daily on a shared

cloud server managed by PI Hughes, with each study assigned a unique ID and associated metadata recorded for all studies.

In addition, existing/secondary data on water quality (e.g., chlorophyll *a*, nutrient concentration, salinity, temperature, etc.), fish and macro-invertebrate abundance, and oyster growth, recruitment, and landings collected by ANERR, FDACS, and FWCC will be used to compare broad patterns identified in the synthesis with recent and current provision of ecosystem services by natural, public oyster reefs in Apalachicola Bay (see Table 1). ANERR, FDACS, and FWCC datasets provide relatively long-term (10-20 years) data on environmental conditions and local stressors affecting the Apalachicola Bay oyster fishery and associated ecosystem services. ANERR, FDACS, and FWCC have established QA/QC requirements for the collection of their data, which have been used by academic universities, government agencies, and private institutions for research and synthesis. The sources of all data used in the synthesis and Apalachicola Bay analysis will be listed and cited in all reports and peer-reviewed publications.

C) Method Development N/A

D) Development or Refinement of Models N/A

E) Development or Operation of Environmental Technology N/A

F) Survey Data

Collection of survey data will follow the same quality control procedures as described above for the collection of new/primary data (see *B.1*) and will be conducted under the auspices of Northeastern University's Institutional Review Board. The proposed sampling strategy, which includes sending survey invitation postcards with pre-notifications, incentives, and reminders, combined with mailing printed surveys to a subsample of 20%, has been used successfully by PI Scyphers in previous surveys of coastal residents in the Gulf Coast (Scyphers et al. 2014, 2015, In Revision) and consistently generated response rates of 20% or greater. Based upon these response rates and a mailing of 2,000 surveys, we expect a sample size of at least 400. The expected response rates will provide sufficient statistical power to conduct classification tree analysis and run logistic regression models, both of which are statistical techniques that have been successfully employed in earlier studies examining comparable social-ecological datasets (Scyphers et al. 2014, 2015, In Revision). Classification tree analysis is particularly effective at elucidating the most powerful predictors of heterogeneity in values, beliefs, and social norms.

G) Data Management

To comply with quality control procedures, data assessment will be regularly conducted during the data collection phase of the project. Field logs and field and laboratory datasheets will be checked by PIs to confirm sample identification is correct and to identify any misidentified samples, which will be destroyed. In addition, datasheets will be photographed, photocopied, or scanned on the day of collection and copies stored in separate locations. PI Hughes will keep original field logs and data sheets. Data entry, including accompanying metadata, will be completed within one week and inspected for data transcription errors by PIs. Upon completion of QA/QC checks, data will be added to a database on a shared cloud server managed by PI Hughes.

HUMAN SUBJECTS RESEARCH STATEMENT

***Note:** In addition to responding to the RFP Specific Criteria listed below, we have also included Northeastern University's formal Policy on Human Subjects Research.

1. Human Subjects involvement, characteristics, and design: Describe the proposed involvement of human subjects in the work being proposed.

Our proposed study involves human subjects research through surveys, interviews, and focus groups. All participants will be at least 18 years of age. There are no other gender, ethnicity/race, socioeconomic level, literacy level, or health criteria for inclusion or exclusion.

2. Benefits of research/value to society: Discuss the potential benefits of the research to the research participants and others, including the value of the knowledge to be gained by the research.

This project has the potential to directly benefit the study community by enhancing planning and management capabilities to promote long-term resilience and sustainability of the oyster fishery. Specifically, our study will strengthen The Nature Conservancy's Coastal Resilience online mapping tool (http://maps.coastalresilience.org/gulfmex) that supports restoration and recovery decisions in planning to maximize ecological, social, and economic benefits.

3. Potential risks to subjects: Describe the potential risks to human subjects (e.g., physical, psychological, financial, legal, or other) and assess their likelihood and seriousness to the human subjects.

We expect this research involves no more than minimal risk for any category. Our previous work of similar nature has been reviewed and approved by Northeastern University's Institutional Review Board and approved as "Exempt" or "Expedited."

4. Protection against risks: Describe planned procedures for protecting against or minimizing potential risks and assess their likely effectiveness.

All data will be stored on laptop computers maintained by PIs Hughes and Scyphers. The computers used by the PIs are password protected, feature data encryption software, and are stored under lock and key.

5. Protection of privacy and confidentiality: Describe how data, specimens, and/or records will be collected, managed, and protected, including at collaborating sites, if any, as well as at the primary site.

For both of the surveys, we plan to conduct follow-up interviews with survey participants at yearly intervals for the project duration. The ability to reconnect with survey respondents and measure changes in their perceptions is an essential component of our study and would be necessary to understand the impacts of environmental changes on individuals and small groups. To achieve this but assure confidentiality, survey responses and interviews will be geo-referenced at the parcel-

level using a unique identifier (individual password printed on the postcard) to allow spatial analyses. For analyses, data will be aggregated at the level of ZIP or census block. Only project PIs Hughes and Scyphers will have access to the key for linking responses to a subject's identity or contact information for the respondents.

6. Protection of vulnerable groups: Explain the rationale for inclusion of vulnerable populations and describe the additional protections in place, if any, for protecting vulnerable populations in the research.

All participants will be at least 18 years of age. There are no other gender, ethnicity/race, socioeconomic level, literacy level, or health criteria for inclusion or exclusion.

7. Risk/benefit relationship: Justify how the risks are reasonable in relation to expected benefits.

This project has the potential to directly benefit the study community by enhancing planning and management capabilities. We expect this research involves no more than minimal risk for any category. Thus, we consider the potential benefits to significantly outweigh any potential risk.

8. Informed Consent Process: Describe planned procedures for the process of obtaining and maintaining informed consent. Include a description of the circumstances under which consent will be sought and obtained, who will seek it, the nature of the information to be provided to prospective subjects, and the method of documenting consent.

We will follow Northeastern University's Consent Process guidelines to develop signed and unsigned consent statements to be used in all surveys, interviews, and focus groups. NU's official Consent Process can be found here: http://www.northeastern.edu/research/hsrp/consent-process/.

9. Relationship between researcher and community: If the research will take place in a community setting, describe the procedures in place for defining the community, obtaining its involvement in the research, and establishing and maintaining trust.

This proposed study system of Apalachicola, Florida is an ideal setting for studying the societal-environmental dimensions of shellfish harvest, aquaculture, ecosystem services, and human health concerns. Our proposed work involves direct partnerships with a key local community-based organization (See letter from Franklin's Promise) and environmental groups (See letter from The Nature Conservancy).

Northeastern University Policy on Human Subjects Research

I. Purpose and Scope

Northeastern University is committed to the ethical conduct of research, and strives to adhere to the highest ethical standards for the protection of human subjects,

consistent with the principles of the Nuremberg Code and the Belmont Report. Accordingly, the University has established the Office of Human Subject Research Protection (HSRP), which provides central administration for the University's Institutional Review Board. The Institutional Review Board provides a procedural framework for meeting the ethical and legal requirements that the rights and welfare of human subjects receive adequate protection. This policy applies to all research involving human subjects conducted by faculty, staff, and/or students at the University, except that research conducted or assigned as part of their coursework is governed by the Policy on Classroom Research.

II. Definitions

For purposes of this policy:

Research means a systematic investigation, including research development, testing and evaluation, designed to develop or contribute to generalizable knowledge. Activities which meet this definition constitute research for purposes of this policy, whether or not they are conducted or supported under a program which is considered research for other purposes. For example, some demonstration and service programs may include research activities.

Human Subjects as defined under federal regulations, means "a living individual about whom an investigator (whether professional or student) conducting research obtains 1) data through intervention or interaction with the individual, or 2) identifiable private information." 45 C.F.R. § 46.102.

Investigator or principal investigator means any individual who is involved in conducting human subjects research studies, including without limitation those performing various tasks related to the conduct of human subjects research activities, such as obtaining informed consent from subjects, interacting with subjects, and communicating with the IRB.

III. Policy

It is the policy of Northeastern University that no activity involving human subjects be undertaken until those activities have been reviewed and approved by the University's Institutional Review Board (IRB). Accordingly, all proposals for university research involving human subjects must first be submitted to the Office of Human Subject Research Protection for IRB review and approval.

In addition, Northeastern University requires completion of training on the protection of human subjects and the ethical principles of research for all human subject research, regardless of whether or not investigators have received funding to support their project. This training is mandatory for all faculty, staff, and students who conduct/supervise research involving human subjects whether on campus or off-campus, whether funded or unfunded.

The principal investigator is responsible for the protection of participants in human subjects research. Safeguarding the participants from undue risk is the ethical responsibility of each person who is involved, either directly or indirectly, in conducting research at Northeastern University. Principal Investigators must require that each member of the research team carries out all research procedures in accordance with ethical principles of research.

The faculty at Northeastern may not recruit students from their own classes for their faculty research projects.

The IRB has the authority to suspend or terminate approval of research that is not being conducted in accordance with the IRB requirements or that has been associated with harm to subjects. Investigators whose research does not comply with university policies may not obtain HSRP review or approval for other human subjects research activities for themselves or their students until the compliance issues have been cleared. Regulations require that HSRP report violations of university policies or federal regulations to the appropriate officials.

Information regarding approval procedures and other necessary guidelines for human research at the University are found at the HSRP website, in Policies and Procedures for Human Research Protections at http://www.northeastern.edu/research/hsrp/manual/. Investigators are responsible for adhering to the guidelines provided, and should read the Policies and Procedures prior to submitting an application for review.

IV. Additional Information

Performing research with human subjects without prior IRB approval is unethical and illegal. Moreover, any violation of research guidelines by the university or an investigator jeopardizes the University's Policy on Human Subjects Research Page 3 10/15/2014 Federal Wide Assurance agreement approved by the United States Department of Health and Human Services, and threatens the University's federal funding. A project that is conducted without IRB approval is subject to termination and/or other action by the University, and may be subject to disciplinary action up to and including termination or separation, and/or criminal or civil legal action.

V. Contact Information

For information about human subjects research and the procedures for applying for IRB review, visit the HSRP website: http://www.northeastern.edu/research/hsrp/ or call (617) 373-4588.

Research participants with questions may contact HSRP via telephone at (617) 373-4588, or via email at n.regina@neu.edu.

COMMUNITY ENGAGEMENT AND COMMUNICATIONS PLAN

Our community engagement and communications activities will leverage existing valuable relationships in our study community, a collaborative research approach guided by stakeholder input, and a funded collaboration with Franklin's Promise Coalition (www.franklinspromisecoalition.org; see letter from Franklin's Promise), a community-based organization in Apalachicola, FL, that actively partners with all sectors of this under-served community. Of particular relevance for this proposal, Franklin's Promise sponsors the Seafood Management Assistance Resource and Recovery Team (SMARRT), a 15-member task force of opinion leaders and decision makers in the community involved in the seafood industry. SMARRT focuses on programs that impact the health and sustainability of Apalachicola Bay and the production of seafood, and they will serve as an important communication conduit to our primary stakeholder groups. Franklin's Promise will facilitate relationships with stakeholders, organize and lead our annual focus groups, help to coordinate in-person interviews to complement our surveys, as well as provide a continual assessment of community attitudes and values throughout the project. We have included funding in our budget for participant support costs for focus groups and building organizational capacity.

Another primary component of our community engagement and communications strategy is our funded partnership with The Nature Conservancy (TNC; see letter from TNC). TNC leads the Coastal Resilience program (http://coastalresilience.org), a public-private partnership to examine the ecosystem services of reduced coastal flood risk. The program consists of an approach, a web mapping tool, and a network of practitioners around the world supporting hazard mitigation and climate adaptation planning. We have budgeted resources to further customize the Restoration Explorer web app within the Coastal Resilience program to identify oyster restoration projects at the site scale that meet social, economic, and ecological needs. Specifically, in collaboration with TNC, we will develop a new "Management Effectiveness" (ME) web app to allow local stakeholders to draw spatially-explicit social-ecological relationships to visualize and analyze potential restoration solutions using a variety of oyster management strategies. In addition, we will conduct a training workshop that includes usability testing and a webinar series to share information on the ME app with communities and practitioners across the Gulf of Mexico.

Below we detail our target audiences, anticipated messages, and anticipated methods; the associated outputs and outcomes are summarized in Table 3.

Target audiences

Oyster harvesters, including private leaseholders and harvesters working primarily on public reefs.

Seafood processers, which will include those specializing on oysters, as well as other seafood species.

SMARRT, which represents all sectors of the seafood community in Apalachicola, FL.

General public, which will be engaged in our surveys and focus groups discussing problems, issues, and solutions.

Planners and decision-makers, including those with responsibility for oyster management, such as municipal/state planners, conservation practitioners, resource authorities, and elected/appointed officials.

Scientific researchers will ensure that collected data within the region are useful and used, that research gaps and needs are identified, and that data quality adheres to Quality Assurance standards. The results of the study, including new ecological and social data, will also be communicated at local, regional, and national meetings.

Anticipated messages

Sustainable oyster fisheries support healthy ecosystems and human well-being - Oysters provide a wide array of ecosystem services, including fisheries enhancement, water purification, and coastal protection, and social values associated with these services contribute directly to individual and community well-being.

Oyster ecosystem services are influenced by human activities - Human-induced stressors such as pollution, over-harvesting, reduced water quality, and coastal development can negatively impact the ecosystem services provided by oysters and the sustainability of the oyster fishery.

Existing ecological data can be used in concert with societal and economic information to improve management effectiveness - The combination of ecological, social, and economic data can greatly enhance decision-making by facilitating the design of management plans that achieve both socially and ecologically desirable outcomes.

A diversified oyster fishery could enhance the sustainability of harvestable oysters and oyster ecosystem services - Assessment of the ecosystem services provided by each oyster management context and documentation of local attitudes, beliefs, concerns, and values regarding oysters, coastal ecosystems, and stressors supports existing communities by considering the feasibility and success of a diversified oyster fishery in a complex social-ecological system.

A diversified oyster fishery could increase the adaptive capacity of the industry - With multiple environmental and anthropogenic stressors threatening the social, ecological, and economic resilience of the oyster fishery in coastal communities like Apalachicola, FL, promoting the sustainability of this social-ecological system requires a diverse management approach. The capacity of the industry to adapt to stressors and support existing community social values will potentially be greater with a range of spatially separated management contexts that experience different, decoupled stressors.

Oyster aquaculture has ecological and social implications that need to be better understood - Determination of which oyster management context(s) minimize the risk of exposure of both oysters and humans to the pathogen *Vibrio*, which poses a threat to human health, is vital to preserving the health and well-being of communities that rely on the oyster fishery.

Information is available to help with resource management decisions - Ecological data, online planning tools, best practices, and other materials will be available to help inform decision-making, learn about the local environment, and understand issues related to coupled human/natural systems. The cornerstone resource is a “Management Effectiveness” web app.

Anticipated methods

Individual and group meetings will be held initially with stakeholders to inform our ecological site selection and survey design.

Societal survey of coastal residents in the first and last years of the project, which will provide a reciprocal interaction with the community. The second survey will be developed based on the results of the first survey and our ecological synthesis. Survey results will be made freely available to participants and the general public.

Follow-up interviews and focus groups will be convened with key stakeholder groups in each year of the project, organized by Franklin’s Promise. Additional in-person interviews and focus groups will be conducted to complement the surveys, particularly with community members under-represented in the survey. We anticipate 10-15 participants per focus group, who will be recruited to reflect diverse attitudes towards oyster management, restoration, and aquaculture.

Field settings will be used for training students in scientific methodology and communication, and provide a valuable opportunity for direct interactions with local oyster harvesters.

Printed materials will be prepared by TNC to communicate project findings to stakeholders and the public.

Decision support tools and training workshops will be used to communicate with natural resource managers and decision makers. Specifically, ecological and social data will be incorporated into TNC's Management Effectiveness web app. A training workshop with key stakeholders will be conducted to assess usability and ensure maximum ease-of-use when applying the tool to local planning.

Public meetings and outreach will include presentation of our findings locally at public meetings and workshops sponsored by the Apalachicola National Estuarine Research Reserve (ANERR), as well as at SMARRT meetings. We will also present at regional conferences such as the Interstate Shellfish Sanitation Conference that focuses on shellfish effects on human health, and at national conferences such as the Ecological Society of America, Society for Human Ecology, and the International Conference on Shellfish Restoration.

Table 3. Summary of expected inputs, outputs, and outcomes of the proposed research in Apalachicola Bay, FL.

Inputs	Outputs			Outcomes
	Activities	Participants	Deliverables	
Oyster fishery collapse Existing ecological data Scientific expertise Community leadership and expertise (Franklin's Promise) Stakeholder input TNC Coastal Resilience Tool	Data synthesis Collection of new ecological data	Oyster harvesters Seafood processers SMARRT task force Community-based organizations General public Natural resource managers and decision makers	Synthesis of oyster ecosystem services New data on lease and aquacultures services	Enhanced access to and use of existing data Ecosystem services of on and off bottom leases
	Survey of community perceptions and values		Characterization of social values and concerns of stakeholders	Increased communication among stakeholders
	Engagement with stakeholders through focus groups and community meetings		Enhancement of decision support tool through integration of ecological and social data Project Fact Sheet	Stakeholder access to ME decision support tool for restoration and management Framework for other coastal communities

DATA PLAN

Types of samples, data, physical collections, and software code

Ecological Data: We will utilize the Knowledge Network for Biocomplexity (KNB: http://knb.ecoinformatics.org/index.jsp), a national network that provides an efficient way to access complex ecological and environmental research data. The KNB network provides access to a database that allows development of metadata specification, Ecological Metadata Language (EML: http://knb.ecoinformatics.org/software/eml/), which was developed by the Ecological Society of America and associated efforts (Michener et al. 1997). EML uses XML documents to organize ecological data into individual modules that describe the project's overall metadata. Our proposed research will use EML to facilitate data sharing. To submit data to EML, we will use the Morpho Data Management software (http://knb.ecoinformatics.org/morphoportal.jsp), which will allow us to manage our data to create suitable metadata modules. These databases are easily accessible, as they are based on Java, which works with Windows, Macintosh, and UNIX operating systems, allowing access to multiple operating system users and increasing collaboration efforts with other researchers.

In years 1 and 2, we will collect monthly oyster samples during the peak growing season that will be preserved on ice and shipped to NEU and stored at -80^{o}C until processing. A subsample of oyster tissue will also be used for disease analysis. These samples will generate new ecological data on oyster growth and biomass, oyster physical characteristics and appearance, and *Vibrio* prevalence and bacterial concentrations across three oyster management contexts – public, natural reefs, private on-bottom leases, and private, off-bottom aquaculture. During our monthly sampling, we will also collect data on fish and invertebrate abundance; all organisms will be identified and measured in the field and then released. Software code used in analysis for publications will be made available via the metadata or other appropriate web repositories (e.g., Dryad) upon publication.

Human Subjects Data: All survey data will be collected under the auspices of Northeastern University's Institutional Review Board. PI Scyphers currently has active IRB protocols for ongoing surveys of coastal residents and recreational and commercial fishers (Protocols #12-05-17, #12-07-25, #12-11-25). Federal Geographic Data Committee (FGDC) compliant metadata will be created and uploaded to the FGDC database (www.fgdc.gov). Northeastern University's Institutional Review Board guidelines will be followed for preparation and archival of data involving human subjects.

Standards to be used for data and metadata format and content

We will use standards-based metadata for all measured variables to 1) publicize project datasets through the relevant repositories, 2) classify data according to our data access policy, 3) maintain knowledge of the composition, organization, and quality of the data, and 4) document detailed data schema to ensure easy and complete understanding of the dataset.

Policies for accessing and sharing data

Summary data will be available within one year of collection. Raw data will be uploaded within three years or less of collection. Our data access policy will include two levels of data access: “private” and “public”. Data classified as “private” represents data that is not ready for publishing. This might include data that has not undergone quality control or data considered proprietary until the PIs have published it. Data that are classified as “public” include all data that are not classified as “private” and are assumed to be freely accessible to anyone. Our Data Access Policy assumes that all data will be classified as “public” within 3 years of collection. If necessary, we will add additional levels of data access to address special circumstances.

Policies and provisions for re-use, re-distribution, and the production of derivatives

Users will be required to provide their name, affiliation, email address and contact information prior to receiving data, and agree to acknowledge this project and cite the dataset in any publications or derivative projects.

Plans for archiving data, samples, and other research products in a timely manner

Short term: Data sheets will be scanned or photocopied on the day that data are collected, with copies stored in two separate locations. Electronic files will be backed up the day that data are entered, with at least one copy in a remote location.

Long term: All ecological data will be aggregated on a shared cloud server managed by PI Hughes. This server will be automatically linked to the KNB. Any remaining oyster tissue samples will be stored at -80^{o}C in the Hughes lab and made available by request. All human subjects data and resulting publications will be archived in Northeastern University's Digital Repository Service (DRS). DRS is a publicly-available digital archive that collects, manages, preserves, and shares the intellectual and historical record of Northeastern University.

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612.
Scyphers S. B., M. W. Beck, J. Haner, A. G. Keeler, C. E. Landry, B. M. Webb, J. H. Grabowski. In revision. Values, beliefs, and incentives for promoting residential shoreline restoration. Conservation Letters
Scyphers, S. B., J. S. Picou, R. D. Brumbaugh, S. P. Powers. 2014. Integrating societal perspectives and values for improved stewardship of a coastal ecosystem engineer. Ecology and Society **19**:38.
Scyphers, S. B., J. S. Picou, and S. P. Powers. 2015. Participatory Conservation of Coastal Habitats: The Importance of Understanding Homeowner Decision Making to Mitigate Cascading Shoreline Degradation. Conservation Letters **8**:41–49.
Scyphers, S. B., S. P. Powers, K. L. Heck, Jr., and D. Byron. 2011. Oyster reefs as natural breakwaters mitigate shoreline loss and facilitate fisheries. PLoS ONE **6**:e22396.
Staley, C., E. Chase, and V. J. Harwood. 2013. Detection and differentiation of *Vibrio vulnificus* and *V. sinaloensis* in water and oysters of a Gulf of Mexico estuary. Environmental Microbiology **15**:623–633.
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Wells, H. W. 1961. The fauna of oyster beds, with special reference to the salinity factor. Ecological Monographs **31**:239-266.
Wilber, D. H. 1992. Associations between freshwater inflows and oyster productivity in Apalachicola Bay, FL. Estuarine, Coastal and Shelf Science **35**:179-190.
Wright, A. C., V. Garrido, G. Debuex, M. Farrell-Evans, A. A. Mudbidri, and W. S. Otwell. 2007. Evaluation of Postharvest-Processed Oysters by Using PCR-Based Most-Probable-Number Enumeration of *Vibrio vulnificus* Bacteria. Applied and Environmental Microbiology **73**:7477–7481.
Zu Ermgassen, P. S., M. D. Spalding, B. Blake, L. D. Coen, B. Dumbauld, S. Geiger, J. H. Grabowski, R. Grizzle, M. Luckenbach, K. McGraw, W. Rodney, J. L. Ruesink, S. P. Powers, and R. Brumbaugh. 2012. Historical ecology with real numbers: past and present extent and biomass of an imperilled estuarine habitat. Proceedings of the Royal Society B: Biological Sciences **279**:3393-3400.

Budget Justification

We are requesting a 3-year project period beginning in April 2017 and ending in March 2020.

1. Personnel - PI Hughes is requesting one month of summer salary, calculated as 1/8 of her base academic salary ($(b) (4)), in each year of the project. Co-PI Scyphers also requests salary ($(b) (4) per year) for 1.0 month in years 1-3. Their time will come in the form of project oversight, field work, laboratory analysis, data analysis, and manuscript preparation. We have budgeted for salary ($(b) (4) per year) for Postdoc Hanley for 6 months in year 1 and 12 months in year 2 to lead oyster sample/data processing and data analysis. We are also requesting funds for stipend ($1500 per month) for one Masters student in the Northeastern Three Seas program for 8 months in each year of the project to conduct field work and data analysis. Finally, we have requested salary ($25,784 per year) for 4 six-month Northeastern undergraduate coop students (1 in years 1 and 3 and 2 in year 2) to conduct surveys and field work.

2. Fringe – Fringe is calculated as 24.7% of faculty and postdoc salaries and 7.65% of student salaries.

3. Travel - We are requesting funds to cover flight costs ($500 per trip), rental car fees ($300 per trip), and research station housing ($25 per night for 7 nights) for senior personnel (Hughes, Scyphers, Hanley) to travel from Boston, MA to Apalachicola, FL to assist with field work (5 trips in each of years 1 and 2; 3 trips in year 3). In addition, we have budgeted funds for the round-trip mileage (2800 miles at $0.545 per mile) and hotel costs (2 nights at $100 per night) for the students to relocate from Boston, MA to Apalachicola, FL (1 trip in years 1 and 3; 2 trips in year 2). As stipulated in the proposal guidelines, we are requesting funds for flight ($300 per) and hotel ($125 per night for 2 nights) for PIs Hughes and Scyphers to attend project meetings in Washington, DC in each year of the project. Finally, we request $3000 in years 2 and 3 for registration, hotel, and flight costs for project personnel to travel to scientific conferences.

4. Equipment - None requested.

5. Supplies – We are requesting $9,300 in year 1 and $6,800 in year 2 for supplies for our field sampling. In year 1, these funds will cover the following expenses: trawl net ($1000); wetsuits (2 at $300 per); foul weather gear (2 at $300 per); GPS unit ($300); boat time (3 days per month for 9 months at $100 per day); oysters for disease and condition analysis ($1 per oyster for 450 oysters per month for 9 months); and miscellaneous supplies ($500). In year 2, we will only need funds for boat time (3 days per month for 9 months at $100 per day), oysters for disease and condition analysis ($1 per oyster for 450 oysters per month for 9 months), and miscellaneous supplies ($500). We are also requesting $9000 in years 1 and 2 for laboratory supplies (molecular reagents, plastic consumables, etc.) to analyze all oyster samples for disease ($2.50 per sample for 3600 samples per year).

6. Contractual – We are requesting $2500 per year for Franklin's Promise, a community coalition that serves to improve residents' quality of life and advocate for the Apalachicola Bay community, to help (1) coordinate in-person interviews following up on mailed surveys; (2) run focus groups with local practitioners and community stakeholders to complement mailed surveys and in-person interviews; (3) organize working relationships with fisherman for paid boat time to facilitate field sampling; and (4) facilitate community outreach for communication of results on the resilience and sustainability of different management contexts for the Apalachicola oyster fishery.
In addition, we are requesting $5,000 in year 1, $20,000 in year 2, and $10,000 in year 3 for a contract to The Nature Conservancy (TNC). TNC will extend the Coastal Resilience decision support tool in the Gulf of Mexico by developing and refining a "Measure Effectiveness" app for the Oyster Restoration Dashboard that incorporates the ecological and social data we will collect. The app will provide valuable insight into the best management strategies to sustain the oyster fishery and associated ecosystem services, while also increasing community resilience and promoting human health and well-being. TNC will develop and test the Measure Effectiveness web app in years 1-2 and complete the app and enhance it based on stakeholder feedback in year 3. TNC will also help manage data from Objective 2.

7. Other -
Printing Costs: We request $5000 in years 1 and 3 to cover the printing and postage costs for our socioecological surveys.
Shipping Costs: We request $2400 in years 1 and 2 ($200 per month) to cover the costs of shipping samples to Northeastern for processing.
Publication Costs: We request $2000 in years 2 and 3 to defray publication fees.

8. Indirect costs – Northeastern University's federally negotiated indirect cost rate is 54.5% on modified total direct costs. Northeastern's cognizant agency is DHHS, New York Office. Federal Point of Contact: Michael Stanco, 212-264-2069.

(Anne) Randall Hughes

Northeastern University Marine Science Center
430 Nahant Road
Nahant, MA 01908
Phone: (781) 581 7370; FAX (781) 581 6076; email: rhughes@neu.edu

A. Professional preparation

University of North Carolina, Chapel Hill	Biology / Public Policy	B.A., 1993-1997
University of California, Davis	Ecology	Ph.D., 2000-2006
University of California, Davis	Marine Ecology	Postdoc, 2006-2008

B. Professional appointments

Assistant Professor	Northeastern University	Jan. 2013-present
Assistant Scholar Scientist	Florida State University	2008-2012

C. Publications

Five publications most relevant to proposed research (out of 37 total); † post doc; ‡graduate student; †† undergraduate student

Hughes, A.R., D.A. Mann, and D.L. Kimbro. 2014. Predatory fish sounds can alter crab foraging behavior and influence bivalve abundance. *Proceedings of the Royal Society B* 281:20140715. http://rspb.royalsocietypublishing.org/content/281/1788/20140715

Hughes, A.R. 2014. Genotypic diversity and trait variance interact to affect marsh plant performance. *Journal of Ecology* 102:651-658. http://onlinelibrary.wiley.com/doi/10.1111/1365-2745.12244/abstract

Hughes, A.R., ††K. Rooker, M. Murdock, and D.L. Kimbro. 2012. Predator cue and prey density interactively influence indirect effects on basal resources in intertidal oyster reefs. *PLoS One* 7:e44839. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0044839

Hughes, A.R. and J.J. Stachowicz. 2011. Seagrass genotypic diversity increases disturbance response via complementarity and dominance. *Journal of Ecology* 99:445-453. http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2745.2010.01767.x/abstract

Hughes, A.R. and J.J. Stachowicz. 2004. Genetic diversity enhances the resistance of a seagrass ecosystem to disturbance. *Proceedings of the National Academy of Sciences* 101: 8998-9002. http://www.pnas.org/content/101/24/8998.full

Five additional publications

Hughes, A.R., †T.C. Hanley, ††N.P. Orozco, and ‡R.A. Zerebecki. 2015. Consumer trait variation influences tritrophic interactions in salt marsh communities. *Ecology and Evolution* 5:2659-2672

Hughes, A.R., ‡A.F.P. Moore, and M.F. Piehler. 2014. Independent and interactive effects of two facilitators on their habitat-providing host plant, *Spartina alterniflora*. Oikos 123: 488-499. http://onlinelibrary.wiley.com/doi/10.1111/j.1600-0706.2013.01035.x/abstract

Hughes, A.R. and K.E. Lotterhos. 2014. Genotypic diversity at multiple spatial scales in the foundation marsh species, *Spartina alterniflora*. *Marine Ecology Progress Series* 497:105-117. http://www.int-res.com/abstracts/meps/v497/p105-117

Hughes, A.R. and J.J. Stachowicz. 2009. Ecological impacts of genotypic diversity in the clonal seagrass *Zostera marina*. *Ecology* 90: 1412-1419. http://www.esajournals.org/doi/full/10.1890/07-2030.1

Hughes, A.R., B. Inouye, M.T.J. Johnson, N. Underwood, and M. Vellend. 2008. Ecological consequences of genetic diversity. *Ecology Letters* 11: 609-623. http://www3.interscience.wiley.com/cgi-bin/fulltext/119419856/HTMLSTART

D. Synergistic activities

Synthetic activities: I have been a member of multiple working groups focused on (1) the effects of genetic diversity in foundation species (sponsored by the European Union); (2) the impacts of the Deepwater Horizon oil spill (sponsored by NSF); (3) global trends in seagrass populations (sponsored by NSF and NCEAS); and (4) ecological and evolutionary insights from invasive species (sponsored by NSF and NCEAS).

Science Outreach: From 2010-2014 I collaborated with a Florida public broadcasting station (WFSU) to produce a blog, numerous short videos, and two documentaries on my research, with the goal of connecting more directly with the public. In 2012, I organized a 2-day science communication workshop for undergraduate and graduate students at FSU. In addition, I taught an undergraduate science communication seminar in 2013 and 2014 at NEU; as a complement to this seminar, I co-organize an annual Career Night aimed at exposing undergraduate and graduate students to science careers outside of academia.

Broadening participation of under-represented groups: I have participated in numerous activities aimed at promoting gender diversity in science, including the NSF ADVANCE Women Evolving Biological Sciences symposium (2011), the Women in Math, Science, and Engineering group at FSU and NEU, and a science summer camp (SciGirls) aimed at fostering the participation of female middle and high school students in the sciences (2008-2012). I have also mentored 2 Iraqi scientists through the Florida State University Fulbright Iraqi Scholars Program.

STEVEN B. SCYPHERS

Address
Northeastern University
Marine Science Center
430 Nahant Road
Nahant, MA 01908
781.581.7370 x324
s.scyphers@neu.edu

Professional Preparation

Auburn University	Marine Biology	B.S.	2007
University of South Alabama	Marine Sciences	Ph.D.	2012
Northeastern University	Sustainability Science	Postdoc	2012 - 2015

Appointments

2015-Present	Associate Research Scientist, Northeastern University
2014-Present	Adjunct Faculty, Northeastern University
2012-Present	NSF SEES Fellow, Northeastern University
2012	Postdoctoral Associate, Northeastern University
2007-2012	Research Assistant, University of South Alabama & Dauphin Island Sea Lab
2007-2008	Teaching Assistant, Dauphin Island Sea Lab

Five Most Relevant Products

1. **Scyphers SB**, JS Picou, RD Brumbaugh, SP Powers. (2014) Integrating societal perspectives and values for improved stewardship of an exploited coastal ecosystem engineer. ***Ecology and Society*** 19(3), article 38.

2. **Scyphers SB**, JS Picou, SP Powers. (2015) Participatory management of coastal habitats: the importance of understanding homeowner decision making to mitigate cascading habitat degradation. ***Conservation Letters*** 8(1), 41-49.

3. **Scyphers SB**, SP Powers, JL Akins, JM Drymon, CW Martin, RH McMichael, ZH Schobernd, P Schofield, RL Shipp, T Switzer. (2014) The role of citizens in detecting and responding to a rapid marine invasion. ***Conservation Letters*** 8(4): 242-250.

4. **Scyphers SB**, SP Powers, KL Heck, D Byron. (2011) Oyster reefs as natural breakwaters mitigate shoreline loss and facilitate fisheries. ***PLOS ONE*** 6(8):e22396.

5. **Scyphers SB** & SB Lerman. (2014) Residential Landscapes, Environmental Sustainability and Climate Change. ***Research in Urban Sociology***, Sustainable Cities: Global Concerns & Urban Efforts, Volume 15:4 (Editor: WG Holt; ISBN: 978-1-78441-058-2).

Five Other Products

1. Scyphers SB, SP Powers, KL Heck. (2015) Ecological value of submerged breakwaters as habitat enhancement at a residential scale. ***Environmental*** **Management** 55(2): 383-391.

2. **Scyphers SB**, SP Powers. (2013) Context-dependent effects of oyster reefs on predator-prey interactions. ***Marine Ecology Progress Series*** 491: 295-301.

3. Powers SP, FJ Fodrie, **SB Scyphers**, JM Drymon, RL Shipp RL, GW Stunz. (2013) Gulf wide decrease of large sharks documented by generations of fishermen. ***Marine and Coastal Fisheries*** 5(1): 93-102.

4. An X, Ganguly AR, Hunter AM, Fang Yi, Scyphers SB, Hunter A, Dy JG. (2014) Tracking climate change opinions from mining Twitter data. ***Proceedings of Data Science for Social Good Workshop at ACM KDD***.

5. **Scyphers SB**. (2012) Restoring oyster reefs along eroding shorelines: an ecological and socioeconomic assessment. Dissertation. University of South Alabama.

Synergistic Activities

1. Appointed Member of the Gulf of Mexico Fishery Mgt. Council Standing Scientific & Statistical Committee.

2. Lead Instructor for *Marine Conservation Biology* in Northeastern University's Three Seas Program and *Sustainable Development* in the Department of Marine and Environmental Sciences. Supervised and mentored twelve undergraduate researchers including an NSF REU. Three students completed research projects that will result in lead or co-author roles on scientific journal articles.

3. I have given more than 40 oral presentations at national and international scientific meetings (e.g. International Marine Conservation Congress) and dozens of outreach talks at workshops including NSF's COSEE Workshop for High School teachers.

3. Editor of *USA Restoration Brief,* a quarterly outreach publication from the University of South Alabama's Oyster Restoration Program and the NOAA Restoration Center. The *Briefs* were widely distributed and seek to inform scientists, managers and the general public about cutting-edge oyster restoration research on a variety of topics. Director of *ShoreLines*, a "Local Interactive Network for Enhancing Sustainability", which involves coastal residents, scientists, conservation groups and local leaders focused on documenting and adapting to coastal change.

Graduate and Postdoctoral Advisors

Sean P. Powers, University of South Alabama	Ph.D.
Jonathan H. Grabowski, Northeastern University	Postdoc
Michael W. Beck, The Nature Conservancy	Postdoc (Partner Mentor)

Torrance C. Hanley

Northeastern University Marine Science Center
430 Nahant Road
Nahant, MA 01908

Phone: (781) 581-7370; Fax: (781) 581-6076; Email: t.hanley@neu.edu

A. Professional Preparation

Cornell University	Biological Sciences / English	B.A., 1998-2002
Yale University	Ecology & Evolutionary Biology	Ph.D., 2002-2009
Yale University	Ecology & Evolutionary Biology	Postdoc, 2009-2011
Northeastern University	Marine & Environmental Sciences	Postdoc, 2013-present

B. Professional Appointments

Faculty	Quinnipiac University	2011-2012

C. Publications

Five publications most relevant to proposed research

Hanley, T.C., A. Randall Hughes, B. Williams, H. Garland, and D.L. Kimbro. *In Press*. "Effects of intraspecific diversity on growth, survivorship, and recruitment of the Eastern oyster across environments." *Ecology* (http://onlinelibrary.wiley.com/doi/10.1890/15-1710.1/abstract)

Hanley, T.C. and K.J. La Pierre (eds). 2015. *Trophic Ecology: Bottom-Up and Top-Down Interactions across Aquatic and Terrestrial Systems*. Cambridge University Press, Cambridge, UK.

Hughes, A.R., **T.C. Hanley**, N.P. Orozco, and R.A. Zerebecki. 2015. "Consumer trait variation influences tritrophic interactions in salt marsh communities." *Ecology and Evolution* 5:2659-2672 (http://onlinelibrary.wiley.com/doi/10.1002/ece3.1564/abstract)

DeLong, J.P., **T.C. Hanley**, and D.A. Vasseur. 2014. "Competition and the density dependence of metabolic rates." *Journal of Animal Ecology* 83: 51-58 (http://onlinelibrary.wiley.com/doi/10.1111/1365-2656.12065/full).

Walsh, M.R., J.P. DeLong, **T.C. Hanley**, D.M. Post. 2012. "A cascade of evolutionary change alters consumer-resource dynamics and ecosystem function." *Proceedings of the Royal Society B: Biological Sciences* (http://rspb.royalsocietypublishing.org/content/early/2012/05/17/rspb.2012.0496)

Five additional publications

La Pierre, K.J. and **T.C. Hanley**. 2015. "Bottom-up and top-down interactions across ecosystems in an era of global change." *Trophic Ecology: Bottom-Up and Top-Down Interactions across Aquatic and Terrestrial Systems* (eds T.C. Hanley and K.J. La Pierre). Cambridge University Press, Cambridge, UK.

DeLong, J.P., **T.C. Hanley**, and D.A. Vasseur. 2014. "Predator-prey dynamics and the plasticity of predator body size." *Functional Ecology* 28:487-493. (http://onlinelibrary.wiley.com/doi/10.1111/1365-2435.12199/abstract)

DeLong, J.P. and **T.C. Hanley**. 2013. "The rate-size trade-off structures intraspecific variation in *Daphnia ambigua* life history parameters." *PLoS ONE* 8: e81024. doi:10.1371/journal.pone.0081024.

Matthews, B., A. Narwani, S. Hausch, E. Nonaka, H. Peter, M. Yamamichi, K.E. Sullam, K.C. Bird, M.K. Thomas, **T.C. Hanley**, and C.B. Turner. 2011. "Toward an integration of evolutionary biology and ecosystem science." *Ecology Letters* 14:690-701. (http://onlinelibrary.wiley.com/doi/10.1111/j.1461-0248.2011.01627.x/abstract)

Hanley, T.C. and A. Caccone. 2005. "Development of primers for the characterization of the mitochondrial control region of Galápagos land and marine iguanas (*Conolophus* and *Amblyrhynchus*)." *Molecular Ecology Notes* 5: 599-601. (http://onlinelibrary.wiley.com/doi/10.1111/j.1471-8286.2005.01004.x/abstract)

D. Synergistic Activities

1) In my tenure at Northeastern University (2013-present), I have led the teaching and training of 2 high school students and 14 NEU undergraduate interns, including 2 students participating in NEU's experience-based learning Cooperative Education Program, and co-mentored 1 NEU graduate student.
2) In 2011-2012, I developed and taught undergraduate lecture and laboratory courses in General Biology for majors and non-majors at Quinnipiac University, emphasizing the importance of communication in science and fostering interest in ecology and conservation biology.
3) I have served as a mentor for Girls, Inc. of Lynn, MA (2014-present), a program that exposes middle and high school girls from underserved communities to science and research, developing and leading marine ecology workshop activities for the after-school and summer programs.
4) I mentored two female high school students, both of whom are currently pursuing degrees in biological sciences, through the Yale Peabody Museum EVOLUTIONS summer internship program (2007-2008), a program that gives high school students with diverse backgrounds the opportunity to develop and conduct their own research projects.
5) I served as a mentor for Women in Science at Yale (WISAY) (2006-2009), a program aimed at promoting gender diversity in science, discussing academic and non-academic career options with my three undergraduate mentees.

United States
ENVIRONMENTAL PROTECTION AGENCY
Washington, DC 20460

OMB Approval No. 2030-0020
Approval Expires 06/30/17

Current and Pending Support

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: A. Randall Hughes	Other agencies (including NSF) to which this proposal has been/will be submitted. None

Support: ☐ Current ☑ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: Managing for social-ecological resilience: Integrating ecosystem function and societal values into a decision-support toolkit for oyster fishery sustainability

Source of Support: Environmental Protection Agency
Total Award Amount: 598,939.00 Total Award Period Covered: 04/01/2017 to 03/31/2020
Location of Project: Northeastern
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 1.00

Support: ☐ Current ☑ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: Collaborative Research: Effects of marine soundscapes on oyster reef trophic interactions and ecosystem function

Source of Support: National Science Foundation
Total Award Amount: 357,232.00 Total Award Period Covered: 11/01/2016 to 10/31/2019
Location of Project: Northeastern
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 1.00

Support: ☐ Current ☑ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: Collaborative Research: Identifying the sources and consequences of intraspecific variation in seaweed response to ocean acidification and warming

Source of Support: National Science Foundation
Total Award Amount: 322,716.00 Total Award Period Covered: 01/01/2017 to 12/31/2019
Location of Project: Northeastern
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 0.50

Support: ☑ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: Collaborative Research: Effects of genetic diversity, epigenetic change, and root-associated fungal colonization on trait variation in a foundation plant

Source of Support: National Science Foundation
Total Award Amount: 179,703.00 Total Award Period Covered: 02/15/2016 to 02/14/2019
Location of Project: Northeastern
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 0.50

Support: ☑ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: Alabama Center for Ecological Resilience (ACER)

Source of Support: Gulf of Mexico Research Initiative
Total Award Amount: 311,602.00 Total Award Period Covered: 01/01/2015 to 12/31/2017
Location of Project: Northeastern
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 0.50

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

OMB Approval No. 2030-0020
Approval Expires 06/30/17

Current and Pending Support

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: A. Randall Hughes

Other agencies (including NSF) to which this proposal has been/will be submitted. None

Support: ☑ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: MA living shorelines for habitat enhancement and coastal resilience

Source of Support: National Fish and Wildlife Federation Hurricane Sandy Coastal Resiliency Program
Total Award Amount: 102,636.00 Total Award Period Covered: 07/01/2014 to 06/30/2016
Location of Project: Northeastern
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 0.25

Support: ☑ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: The importance of fresh water inflow to the ecology and productivity of Apalachicola Bay

Source of Support: Florida Department of Environmental Protection
Total Award Amount: 138,414.00 Total Award Period Covered: 03/01/2015 to 06/30/2016
Location of Project: Northeastern
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 1.50

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal:

Source of Support:
Total Award Amount: Total Award Period Covered: to
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal:

Source of Support:
Total Award Amount: Total Award Period Covered: to
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
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Total Award Amount: Total Award Period Covered: to
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Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

United States
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Washington, DC 20460

OMB Approval No. 2030-0020
Approval Expires 06/30/17

Current and Pending Support

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Steven B. Scyphers	Other agencies (including NSF) to which this proposal has been/will be submitted. None.

Support: ☐ Current ☑ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: Managing for social-ecological resilience: Integrating ecosystem function and societal values into a decision-support toolkit for oyster fishery sustainability

Source of Support: This Proposal
Total Award Amount: 598,939.00 Total Award Period Covered: 04/01/2017 to 03/31/2020
Location of Project: Northeastern University
Person-Months Per Year Committed to the Project. Cal: 1.00 Acad: Sumr:

Support: ☑ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: Social-Ecological Resilience of Coastal Shoreline Ecosystems: Developing a Framework for Informed Decision-Making

Source of Support: National Science Foundation - SEES Fellows Program
Total Award Amount: 503,447.00 Total Award Period Covered: 07/01/2012 to 06/30/2016
Location of Project: Northeastern University
Person-Months Per Year Committed to the Project. Cal: 3.00 Acad: Sumr:

Support: ☑ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: Predicting social impacts of climate change in fisheries

Source of Support: NOAA Climate Program Office
Total Award Amount: 298,950.00 Total Award Period Covered: 08/01/2015 to 07/31/2017
Location of Project: Northeast U.S.
Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: Sumr:

Support: ☑ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: Assessing social impacts in groundfish fishing communities

Source of Support: NOAA Saltonstall-Kennedy Progam (2013 S-K)
Total Award Amount: 236,785.00 Total Award Period Covered: 02/01/2014 to 01/31/2017
Location of Project: Northeastern University
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☑ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: Social and ecological factors influencing shoreline hardening in the Northeast: Implications for vulnerability, resilience, and informed decision making

Source of Support: Northeast Sea Grant Consortium
Total Award Amount: 301,201.00 Total Award Period Covered: 02/01/2014 to 01/31/2017
Location of Project: Northeastern University
Person-Months Per Year Committed to the Project. Cal: 0.00 Acad: Sumr:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

United States
ENVIRONMENTAL PROTECTION AGENCY
Washington, DC 20460

OMB Approval No. 2030-0020
Approval Expires 06/30/17

Current and Pending Support

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Steven Scyphers	Other agencies (including NSF) to which this proposal has been/will be submitted. None.

Support: ☐ Current ☑ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: Engaging commercial, recreational, and subsistence fishers to improve management of striped bass (Morone saxatilis) fisheries in New England

Source of Support: NOAA Saltonstall-Kennedy Program (SK 2016)
Total Award Amount: 240,859.00 Total Award Period Covered: to
Location of Project: Northeastern University
Person-Months Per Year Committed to the Project. Cal: 1.00 Acad: Sumr:

Support: ☐ Current ☑ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: Policy Scenarios for Coastal Communities in Response to Environmental and Social Change: A Collaborative Modeling Approach

Source of Support: National Academies of Science - Gulf Research Program
Total Award Amount: 300,000.00 Total Award Period Covered: to
Location of Project: Michigan State University & Northeastern U.
Person-Months Per Year Committed to the Project. Cal: 1.00 Acad: Sumr:

Support: ☐ Current ☑ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: Collaborative Modeling with Fuzzy Cognitive Maps: a novel approach to achieving safety culture

Source of Support: National Academies of Science - Gulf Research Program
Total Award Amount: 407,000.00 Total Award Period Covered: to
Location of Project: Portland State University & Northeastern U.
Person-Months Per Year Committed to the Project. Cal: 2.00 Acad: Sumr:

Support: ☐ Current ☐ Pending ☑ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: Evaluating the capacity of natural and nature-based features to reduce coastal storm hazards

Source of Support: U.S. Army Corps of Engineers
Total Award Amount: 65,000.00 Total Award Period Covered: to
Location of Project: University of South Alabama & Northeastern U.
Person-Months Per Year Committed to the Project. Cal: 1.00 Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal:

Source of Support:
Total Award Amount: Total Award Period Covered: to
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

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United States
ENVIRONMENTAL PROTECTION AGENCY
Washington, DC 20460

OMB Approval No. 2030-0020
Approval Expires 06/30/17

Current and Pending Support

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Torrance C. Hanley

Other agencies (including NSF) to which this proposal has been/will be submitted.
N/A

Support: ☐ Current ☑ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal: Managing for social-ecological resilience: Integrating ecosystem function and societal values into a decision-support toolkit for oyster fishery sustainability

Source of Support: Environmental Protection Agency
Total Award Amount: 598,939.00 Total Award Period Covered: 04/01/2017 to 03/31/2020
Location of Project: Northeastern University
Person-Months Per Year Committed to the Project. Cal: Acad: 6.00 Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal:

Source of Support:
Total Award Amount: Total Award Period Covered: to
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal:

Source of Support:
Total Award Amount: Total Award Period Covered: to
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
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Source of Support:
Total Award Amount: Total Award Period Covered: to
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

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NCER FORM 5 (9/01) For Use with EPA STAR Grant Applications

USE ADDITIONAL SHEETS AS NECESSARY

Page

FRANKLIN'S PROMISE Coalition.org

Franklin County's Community Coalition

April 20, 2016

Dear Dr. Hughes,

This letter reflects the intent of Franklin's Promise Coalition to participate in your proposed research project "Managing for social-ecological resilience: Integrating ecosystem function and societal values into a decision-support toolkit for oyster fishery sustainability" in Apalachicola Florida.

The proposed project will evaluate ecosystem services provided by oyster habitat in three socio-environmental management contexts (public oyster reefs, private oyster leases, and private aquaculture), their response to multiple stressors, the social values attached to these services, and their implications for ecosystem management and human-well being.

Specifically, the Coalition will assist the project team by identifying key stakeholders and coordinating a series of workshops and focus groups in each year of the project. We anticipate 10-15 participants per focus group who will be recruited to reflect both positive and negative attitudes towards oyster management, restoration, and aquaculture.

We look forward to the opportunity,

Joe Taylor

Joe Taylor, Executive Director
Franklin's Promise Coalition
192 Coach Wagoner Blvd.
Apalachicola, Florida 32320
850-323-0176

The Nature Conservancy
Protecting nature. Preserving life.

Gulf of Mexico Program
311 Berry Street
Punta Gorda, FL 33950

Tel (941) 621-4567 nature.org

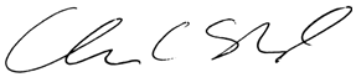
April 20, 2016

Dear Dr. Hughes,

This letter reflects the intent of The Nature Conservancy to participate in your proposed research project "**Managing for social-ecological resilience: Integrating ecosystem function and societal values into a decision-support toolkit for oyster fishery sustainability"** in Apalachicola Florida.

The proposed project will evaluate ecosystem services provided by oyster habitat in three socio-environmental management contexts (public oyster reefs, private oyster leases, and private aquaculture), their response to multiple stressors, the social values attached to these services, and their implications for ecosystem management and human-well being. This work will leverage and enhance The Nature Conservancy's Coastal Resilience online mapping tool (http://maps.coastalresilience.org/gulfmex) that supports restoration and recovery decisions in planning to maximize ecological, social, and economic benefits.

Sincerely,



Christine C. Shepard, Ph.D.
Director of Science, Gulf of Mexico Program
The Nature Conservancy

BUDGET INFORMATION - Non-Construction Programs

OMB Number: 4040-0006
Expiration Date: 01/31/2019

SECTION A - BUDGET SUMMARY

Grant Program Function or Activity (a)	Catalog of Federal Domestic Assistance Number (b)	Estimated Unobligated Funds		New or Revised Budget		
		Federal (c)	Non-Federal (d)	Federal (e)	Non-Federal (f)	Total (g)
1.		$	$	$	$	$
2.						
3.						
4.						
5. Totals		$	$	$	$	$

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Prescribed by OMB (Circular A -102) Page 1

SECTION B - BUDGET CATEGORIES

6. Object Class Categories	GRANT PROGRAM, FUNCTION OR ACTIVITY (1)	(2)	(3)	(4)	Total (5)
	N/A	N/A	N/A		
a. Personnel	$ 67,743.00	$ 108,595.00	$ 45,906.00	$	$ 222,244.00
b. Fringe Benefits	12,488.00	20,194.00	6,836.00		39,518.00
c. Travel	8,500.00	12,500.00	9,500.00		30,500.00
d. Equipment					
e. Supplies	18,300.00	15,800.00			34,100.00
f. Contractual	7,500.00	22,500.00	12,500.00		42,500.00
g. Construction					
h. Other	7,400.00	4,400.00	7,000.00		18,800.00
i. Total Direct Charges (sum of 6a-6h)	121,931.00	183,989.00	81,742.00		$ 387,662.00
j. Indirect Charges	66,453.00	100,274.00	44,550.00		$ 211,277.00
k. TOTALS (sum of 6i and 6j)	$ 188,384.00	$ 284,263.00	$ 126,292.00	$	$ 598,939.00
7. Program Income	$	$	$	$	$

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SECTION C - NON-FEDERAL RESOURCES

(a) Grant Program	(b) Applicant	(c) State	(d) Other Sources	(e)TOTALS
8.	$	$	$	$
9.				
10.				
11.				
12. TOTAL (sum of lines 8-11)	$	$	$	$

SECTION D - FORECASTED CASH NEEDS

	Total for 1st Year	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
13. Federal	$	$	$	$	$
14. Non-Federal	$				
15. TOTAL (sum of lines 13 and 14)	$	$	$	$	$

SECTION E - BUDGET ESTIMATES OF FEDERAL FUNDS NEEDED FOR BALANCE OF THE PROJECT

(a) Grant Program	FUTURE FUNDING PERIODS (YEARS)			
	(b)First	(c) Second	(d) Third	(e) Fourth
16.	$	$	$	$
17.				
18.				
19.				
20. TOTAL (sum of lines 16 - 19)	$	$	$	$

SECTION F - OTHER BUDGET INFORMATION

21. Direct Charges:

22. Indirect Charges:

23. Remarks:

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PEER REVIEW RESULTS SUMMARY 2016

Integrating Human Health and Well-Being with Ecosystem Services

Funding Opportunity Numbers: EPA-G2016-STAR-A1
EPA-G2016-STAR-A2: Early Career Projects

Application Number: G16A112149217
Primary Institution: Northeastern University
PI Name: Randall Hughes
Application Title: Managing for social--ecological resilience: Integrating ecosystem function and societal values into a decision--support toolkit for oyster fishery sustainability

Overall Rating: Good

Criteria are listed in descending order of importance (i.e., Criteria 1 has the heaviest weight).

1. Research Merits: (subcriteria are in descending order of importance):

a. The degree to which the application demonstrates that the research is original and contributes to the scientific knowledge in the topic area. And the degree to which the application demonstrates that the project (and its approach) is defensible and technically feasible, and uses appropriate and adequate research methods.

Strength:

The research is a nice example of a coupled social-ecological system investigation.

Weakness:

Major Weakness
It is not clear in objectives 1 and 2 how the wealth of primary data collection is original nor distinct from current and pending projects.

Objective 3: It is not clear who uses the Restoration Explorer and who will use the Management Effectiveness app. It is important to know whether these are used by decision makers or the general public in order to evaluate the extent of community engagement.

It is somewhat surprising that Vibrio prevalence is not already being tested for. A stronger case could be made for why there is a need for such intensive primary data collection when the focus of the EPA Request for Assistance (RFA) is on use of secondary sources.

Major Weakness
There is not a compelling statement of why this research is original.

It is unclear what structuring framework will be used to integrate the ecological and the survey data. A Decision Support Tool is mentioned but it is unclear how the new data will be incorporated into this tool.

b. The degree to which the application demonstrates that the project results will produce benefits to the public (such as improvements to the environment or human health) and will be disseminated to enhance scientific and technological understanding.

Strength:

Major Strength
The authors propose comparative assessments to identify the benefits and costs of different oyster development scenarios on the oyster resource, human health, adaptation to stressors such as climate change, and water quality.

Weakness:

It is noted that 100 communities worldwide have been trained in the use of the decision support tool, but there is no note on how this has resulted in actual use and outcomes. Maybe this evaluation data does not exist. If so, a lack of mention of results is not a major weakness.

Benefits to the public are to be assessed, but it is unclear from the application what extent of such benefits are to be expected.

2. Responsiveness: The degree to which the application demonstrates that the research is responsive to the objectives, research needs, and special considerations specified by the RFA.

Strength:

Major Strength
The application is organized around the objectives, research needs and considerations in the Request for Assistance (RFA) and as such is directly responsive to the RFA. The Team provides clear Approach and Activities descriptions to meet each objectives.

The use of figures and tables further clarifies how each part of the project fits into the overall RFA objectives and outputs.

This is a comprehensive proposal to evaluate the stressors, public perceptions, management strategies and decision-making approaches with respect to an important community and economic resource.

The proposal duly links ecological and sociological systems. The three research questions are explicitly addressed.

Weakness:

While an array of ecosystem services are listed, there is no proposed examination of the connection of these services to human health.

Objective 2: While great potential, it is not clear how survey and focus groups will yield perceived ecological connections to human health or how the team might use the methods themselves and results to educate stakeholders on these connections.

There is relatively little attention given to "ecosystem services" per se or to human health and well-being. The Nature Conservancy appears to be the primary community partners, which is unlikely to lead to much insight into broader aspects of community well-being.

3. Project Management (subcriteria are equally weighted):

a. Investigators: The degree to which the application demonstrates that the Principal Investigator(s) and other key personnel have the appropriate qualifications (including research training, demonstrated knowledge of pertinent literature, experience, and publication records).

Strength:

Environmental science expertise of most of the team is complemented by the social science expertise of co-PI Scyphers who has experience in surveying the proposed population.

The PI's bring the required expertise and use of partnerships extends the reach of the project and depth of experiences.

The project requires the input of all PIs to capture the necessary expertise.

Weakness:

Minor Weakness
The overall Primary Investigator Dr. Hughes does not emphasize oyster expertise in her CV, but does bring the coastal habitat and marine ecology expertise.

b. Management: The degree to which the application demonstrates that the project will be adequately managed to ensure the timely and successful achievement of objectives using appropriate project schedules and milestones. And the degree to which the application demonstrates the applicant will adequately track and measure progress toward achieving expected results (outputs and outcomes).

Strength:

Table 3 provides details of the inputs, outputs and outcomes with a breakdown by activity, participant and deliverables. This level of organization confirms that the team has clear objectives and goals that will be met using specific actions and team members.

The clear and detailed organization of the project assures that the tracking, measurement of progress and milestones will be met by the team.

Weakness:

There is no process evaluation built in to project schedule.

Relatively little attention is given to how the pieces of the study would be integrated. The project schedule does not show time given to integration of the various pieces, which is essential to gaining new insights.

c. Quality Assurance (QA): The degree to which the application includes an appropriate and adequate QA Statement.

Strength:

The quality assurance approach is clear and specific to each step of the project.

Weakness:

Activities outlined in QA are largely primary data collection which has added potential for unforeseen complexity and may require the need for quality controls beyond study period.

d. Resources and Cost Controls: The degree to which the application demonstrates that the facilities, equipment, and budget are appropriate, adequate, and available. And the degree to which the application demonstrates that well-defined and acceptable approaches, procedures, and controls are used to ensure timely and efficient expenditure of awarded grant funds.

Strength:

The budget appears to adequately support the activities proposed.

Weakness:

Minor Weakness
Dollar amount that will be used as an incentive to complete survey not in budget.

4. Other Factors (subcriteria are equally weighted):

a. Innovation: The degree to which the application demonstrates that the research will challenge and seek to shift current research or engineering paradigms by using innovative theoretical concepts, approaches or methodologies, instrumentation or interventions applicable to one or more fields of research.

Strength:

The innovation of the project lies in its enhancement of an existing online coastal management tool and the creation of a new web app.

There is value in evaluating different oyster harvesting/production approaches.

Weakness:

It is not clear if these innovative online tools will be used by the general public or only by a select few decision makers.

The proposed research and data collection is fairly conventional and is unlikely to challenge current research paradigms. There is not a new framework, hypothesis, or perspective being offered.

b. Sustainability: The degree to which the application demonstrates that the research will embody the principles of sustainability and seek sustainable solutions that protect the environment and strengthen our communities. The sustainability primer (see link) provides examples of research activities that promote and incorporate sustainability principles (Sustainability Primer (PDF) (2 pp, 195 K)).

Strength:

None

Weakness:

The proposed approach to sustainability is very much focused on the environment and less on its reciprocal relationship to social sustainability.

Sustainability is addressed directly but the scope is limited to oyster management without obvious extensions or new principles.

c. Community Engagement and Communications Plan (CECP): The degree to which the CECP clearly describes how communities and stakeholders will be involved in the research and implementation processes, and describes planned interactions with these partners through the course of the project. The degree to which the CECP effectively ensures that communities are supportive of the proposed research and empowered to take action to reduce pollutant exposure, either immediately or in the future. The degree to which the methods of communication and the levels of community engagement are appropriate for the research topic and are likely to have a tangible benefit for communities. The degree to which the applicant has described: [1] an active partnership with a community or community-based organization, [2] the partner's intent to participate in the proposed research and [3] that the applicant or partner has acquired enough data to identify and prioritize public-health and ecological concerns. Applicants that do not plan on partnering with other groups in the performance of the project will be evaluated based on the extent to which they demonstrate how they will be able to effectively perform and complete the project without such partnership.

Strength:

A key partner brings expertise in community outreach in the study communities. This specific expertise will greatly benefit the project.

An array of target audiences with potentially diverse opinions will be involved in the survey and focus groups.

A clear and strong partnership with TNC is demonstrated and built upon in this proposal.

Weakness:

Minor Weakness
Beyond survey work, the community does not appear to be a key participant in formulating the research questions or conducting and interpreting results. Overall, principles of Community Based Participatory Research (CBPR) are not met.

Status of Your Application (ID Number: G16A112149217)

Receipt.Application to: rhughes 07/20/2016 08:42 AM
Sent by: Receipt.Application@epa.gov
Cc: ep.jones

From: Receipt.Application@epa.gov@NotesDomain
To: rhughes@neu.edu,
Cc: ep.jones@neu.edu
Sent by: EPA/ORD/NCER

1 attachment

g16a112149217.pdf

PLEASE DO NOT RESPOND TO THIS E-MAIL

RE: Funding Opportunity Number: EPA-G2016-STAR-A1

Randall Hughes:

Thank you for submitting your application in response to the above-referenced RFA. Your application was peer reviewed by experts in the field and related disciplines in accordance with the terms, conditions, requirements, and criteria stated in Section V of the RFA. However, I regret to inform you that your application was not selected for award consideration because it did not pass the peer review.

The results of the merit review for your application are enclosed. This information is provided for your personal use. It may be helpful to you in preparing future applications.

This communication fulfills the Agency's post review notification procedure for applicants. Should you have any further questions regarding the review of your application, you may contact me within 15 days of the date you receive this letter to schedule a debriefing. Upon receipt of a timely request, I will contact you to schedule a debriefing telephone call at a mutually agreeable time to further discuss the strengths and weaknesses of your application and answer any questions regarding the evaluation procedures.

For additional information about our debriefing process please see the dispute resolution procedures set forth in 70 FR 3629, 3630 (January 26, 2005). These procedures stipulate that applications not selected for award, after a full evaluation based on the ranking and selection criteria listed in Section V of the announcement, are generally not entitled to file disputes with EPA. Should you have any questions, please call me at 202-564-6412 or law.sheryl@epa.gov.

Sincerely yours,

Sheryl Law
Science Review Officer
Policy, Planning & Review Division
National Center for Environmental Research
U.S. Environmental Protection Agency

Enclosures

PEER REVIEW RESULTS SUMMARY 2016

Integrating Human Health and Well-Being with Ecosystem Services

Funding Opportunity Numbers: EPA-G2016-STAR-A1
EPA-G2016-STAR-A2: Early Career Projects

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Primary Institution: Northeastern University
PI Name: Randall Hughes
Application Title: Managing for social--ecological resilience: Integrating ecosystem function and societal values into a decision--support toolkit for oyster fishery sustainability

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Strength:

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Weakness:

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The proposed approach to sustainability is very much focused on the environment and less on its reciprocal relationship to social sustainability.

Sustainability is addressed directly but the scope is limited to oyster management without obvious extensions or new principles.

c. Community Engagement and Communications Plan (CECP): The degree to which the CECP clearly describes how communities and stakeholders will be involved in the research and implementation processes, and describes planned interactions with these partners through the course of the project. The degree to which the CECP effectively ensures that communities are supportive of the proposed research and empowered to take action to reduce pollutant exposure, either immediately or in the future. The degree to which the methods of communication and the levels of community engagement are appropriate for the research topic and are likely to have a tangible benefit for communities. The degree to which the applicant has described: [1] an active partnership with a community or community-based organization, [2] the partner's intent to participate in the proposed research and [3] that the applicant or partner has acquired enough data to identify and prioritize public-health and ecological concerns. Applicants that do not plan on partnering with other groups in the performance of the project will be evaluated based on the extent to which they demonstrate how they will be able to effectively perform and complete the project without such partnership.

Strength:

A key partner brings expertise in community outreach in the study communities. This specific expertise will greatly benefit the project.

An array of target audiences with potentially diverse opinions will be involved in the survey and focus groups.

A clear and strong partnership with TNC is demonstrated and built upon in this proposal.

Weakness:

Minor Weakness
Beyond survey work, the community does not appear to be a key participant in formulating the research questions or conducting and interpreting results. Overall, principles of Community Based Participatory Research (CBPR) are not met.